INFLUENCE OF RENDERED FAT IN THE DIET OF LARGE WHITE YORKSHIRE SOWS ON LITTER PERFORMANCE

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Veterinary Science

Faculty of Veterinary and Animal Sciences
Kerala Agricultural University

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COLLEGE OF VETERINARY AND ANIMAL SCIENCES
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KERALA, INDIA

2003

DECLARATION

I hereby declare that the thesis, entitled **"INFLUENCE OF RENDERED FAT IN THE DIET OF LARGE WHITE YORKSHIRE SOWS ON LITTER PERFORMANCE"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

THIRUVENI, S.

Mannuthy,
5.5.2003

There are no words to express my deep sense of gratitude and hence the bouquets of special thanks are due to my friends ***Babitha, Bindu Mathew, Bindu. P, Bindu Raj, Bisi, Deepa, Elizabeth, Shameem, Sajitha*** *and* ***Smitha.J.P*** *for showering their love and affection on me and making my stay here comfortable.*

I take this opportunity to express my deep sense of love and affection towards my best friends ***Priyadharshini, Rajendran, Manju, Asitha, Jyotsana, Poornima, Mythili, Rekha, Julie, Arthur, Manoj, Thanda, Rana*** *for their support, memorable concern and warm friendship.*

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I wish to acknowledge ***Dr. P. X. Antony*** *and* ***Dr. D. Prasanna*** *for their words of inspiration and encouragement for the successful completion of the thesis work.*

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Last but not the least, thanking ***Almighty*** *for timely providing of all the needs to me because of the blessings, prayers and love of my* ***Amma*** *and* ***Appa.***

THIRUVENI, S.

CERTIFICATE

Certified that the thesis, entitled **"INFLUENCE OF RENDERED FAT IN THE DIET OF LARGE WHITE YORKSHIRE SOWS ON LITTER PERFORMANCE"** submitted for the degree of M.V.Sc. in the subject of Animal Nutrition of the Kerala Agricultural University, is a bonafide research work carried out by Miss. Thiruveni, S., under my supervision and that no part of this thesis has been submitted for any other degree.

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We, the undersigned members of the Advisory Committee of **Miss. Thiruveni, S.,** a candidate for the degree of Master of Veterinary Science in Animal Nutrition, agree that the thesis entitled **"INFLUENCE OF RENDERED FAT IN THE DIET OF LARGE WHITE YORKSHIRE SOWS ON LITTER PERFORMANCE"** may be submitted by Miss. Thiruveni, S., in partial fulfilment of the requirement for the degree.

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There are no words to express my deep sense of gratitude and hence the bouquets of special thanks are due to my friends ***Babitha, Bindu Mathew, Bindu. P, Bindu Raj, Bisi, Deepa, Elizabeth, Shameem, Sajitha and Smitha.J.P*** *for showering their love and affection on me and making my stay here comfortable.*

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THIRUVENI, S.

Dedicated to

My Amma & Appa

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Introduction

1. INTRODUCTION

Pig farming provides reasonable returns to the farmer considering the low investment needed and the short span for each generation. Pigs are the most efficient among domestic animals in the conversion of feedstuffs and wastes of domestic and agro-industrial origin into edible meat. Thus, swine production has a great importance and plays a significant role in improving the socio-economic status of a sizeable section of the rural community.

The ultimate success of pig rearing largely depends on the supply of nutritionally balanced economical rations. But the requirement for energy may not always be satisfied either because the management system limits the maximum amount supplied to sows or because of the inability of the sow to consume large quantities of feed. The probable results of either situation are reduced milk yield and excessive loss of body weight. Reduced milk yield is likely to depress piglet viability and growth rate, while excessive weight loss will adversely affect post-weaning reproductive performance and productivity of sows in later cycles.

Neonatal mortality represents a major loss to the swine industry. The majority of these deaths occur during the first three days after farrowing with losses typically in the range of one or two pigs per litter. By far, the most important factors in piglet losses are physiological immaturity and lack of stored energy in the baby pig that result in an overall lack of vigor, inability to survive, crushing and malnutrition (or starvation). Body energy reserves at birth are low and can supply the energy for only 12 to 15 hours in the typical birth environment conditions of 18 to 21° C. Malnutrition accounts for 80 per cent of piglet mortality (English *et al.*, 1979).

Thus, the viability of the piglet around farrowing and during the critical first day after birth is highly dependent on its energy reserves, which are related to body weight at birth and ingested colostrum. The energy reserve is built during prenatal growth. Hence,any increase in the energy reserves of the piglet prenatally is likely to improve its chances of survival in the early postpartum period and to perform well in the future life. Energy deficiency during pregnancy period of sow is associated with lower body fat reserves at farrowing and lactation leading to delayed onset of postpartum estrus and poor conception rate in the ensuing reproductive cycles. Hence, the period of pregnancy appears also to be the main period during which the body reserves of the sows can be restored.

Until recently, swine nutritionists focussed on the utilization of feed ingredients available in the market which were costly. Agro-industrial waste materials and the wastes available from slaughter house and seafood industries are found to be valuable and can be used in feed formulation to reduce the cost of production. Rendered animal fat is one such product which is available in Kerala at a low cost. Animal fats used in animal feeding are mainly beef tallow, lard, mixed animal fats. The sources of the animal fat include slaughterhouse waste, trimmings and fat from rendering plants. The animal feed industry provides the main outlet for animal fat disposed of by rendering plants.

A limited gain during pregnancy and a maximum conservation of weight during lactation is theoretically the most efficient way of feeding of sows. So, the present investigation was taken up to assess the effects of inclusion of rendered animal fat in the diets of Large White Yorkshire sows prior to parturition and during lactation on survival rate and postnatal growth rate of piglets under Indian condition and also to arrive at the economics of its supplementation in their feed.

Review of Literature

2. REVIEW OF LITERATURE

2.1 Animal fat in animal feeding systems

2.1.1 Classification and definition

Boyd *et al.* (1978) defined that bleachable fancy tallow is a lipid source of animal origin differing from corn oil in fatty acid type (highly saturated) and is commercially available.

Sonntag (1979a) stated that the animal fat group consisted of the body fats (Lard, Tallow, etc.) of domestic land animals and they are characterized by a high content of C_{16} and C_{18} fatty acids and a medium degree of unsaturation. They observed that their unsaturated acids are almost entirely oleic and linoleic acids. They are unique in that they contain small quantities of certain odd-numbered straight chain fatty acids and considerable proportions of fully saturated triglycerides.

Overland *et al.* (1994) reported that rendered fat, a by-product of the slaughter industry consists of lard, tallow and poultry fat, etc. and was a commonly used fat source in swine diets. However, they reported that, its utilization was limited due to a high content (44.9%) of long chain, saturated non-polar fatty acids. They observed the predominant saturated fatty acids as palmitic (16:0) and stearic acid (18:0), and the predominant unsaturated fatty acid as oleic acid (18:1).

Gunstone (1996) said that the fats of animal origin included lard from pigs and tallows from cattle and sheep which had been produced by rendering of the carcass tissue.

Cheeke (1999) reported that the animal fat. included tallow (from beef and mutton or lamb) and lard (from pork).

2.1.2 Sources

Cheeke (1999) reported that the sources of animal fats included slaughter house waste, trimmings and fat from rendering plants. According to him feed industry can be the main outlet for these animal fats utilisation.

2.1.3 Extraction

Sonntag (1979b) defined that lard could be obtained by dry or wet rendering procedures. The open kettle (dry) rendering was originally done at atmospheric pressure at a temperature of 230-240°F and now-a-days by vacuum method with a consistent yield of 86-98% from cutting and leaf fats. In wet rendering processes, the fatty tissues were heated in the presence of water usually at lower temperatures than in dry rendering resulting in wild flavored lards and were called as prime-steam lard.

Gunstone (1996) elaborated the extraction procedure in which he stated that the fat was recovered from the land animals by reduction to suitably sized pieces (hashing) followed by steaming in one of two ways. With wet steam, the temperature was raised to about 100°C and the mixture was agitated. After settling, the oil layer was first decanted and then centrifuged. With dry steam (indirect steam heating) the product was put through a screw press and the oil or water mixture was separated with a decanter and a centrifuge. High temperatures were used to deactivate the active enzymes which are present in animal fats from whole animals, depot fats or viscera.

2.1.4 Physical and chemical characteristics

Sonntag (1979b) gave the range of values on the typical characteristics of lard and beef tallow. The range of values for iodine number, saponification number, melting point (Wiley °C) and unsaponifiable matter for lard given by him were 46-70, 195-202, 46-48 and not over one per cent, respectively. The range of values for specific gravity (at 99/15.5°C), refractive index at 40°C (Zeiss), iodine number, saponification number and unsaponifiable matter for beef tallow given by him were 0.86-0.87, 46-49, 35-48, 193-202 and not over 0.8 per cent, respectively. He also defined the rheological properties of lard as those of hardness, consistency and fat penetration which quantified its plasticity characteristics. He further stated that lard is low in polyunsaturated fatty acids as well as in natural antioxidants. The oxidation stability reported was, at best, only fair to average, becoming rancid at 100°C after it had absorbed 10 to 15 per cent of its volume of O_2.

Miller and De Boer (1988) opined that the four chemical and physical characteristics of animal fats which were important for use in animal feeding as stability, purity, free fatty acid (FFA) content and fatty acid profile. They referred stability as the ability to prevent oxidation and rancidity of fats. They also reported that the good quality feed grade fats should have minimum impurities (less than 4 per cent) and FFA content (less than 15 per cent).

Cheeke (1999) reported that the fats are solid at room temperature and the solid nature of fats is mainly due to the presence of lipids containing saturated fatty acids.

2.1.5 Absorbability and digestible energy value

Sibbald *et al.* (1961) reported the apparent metabolizable energy of beef tallow to be 29.5 MJ/kg.

Young and Artman (1961) gave the apparent metabolizable energy (determined as gross energy x percentage absorbability) for lard and beef tallow as 36.2 and 30.7 MJ/kg, respectively (at 16 per cent addition).

Artman (1964) gave the comparative data of apparent metabolizable energy value of tallow as determined by direct calorimetry, fat digestibility and food conversion ratio as 30.4, 27.3 and 35.3 MJ/kg, respectively.

Freeman (1969) explained that the long-chain, saturated non polar fatty acids had a restricted entry into the micellar phase, and consequently the absorption was reduced.

Sibbald and Kramer (1977) determined the total metabolizable energy of tallow as 34 MJ/kg.

Enser (1984) stated that in terms of energy-yielding potential, fat was not an essential dietary ingredient and it could be replaced by carbohydrate.

However, reported that in the nutrition of modern farm animals the high energy density of fat was advantageous.

Freeman (1984) suggested that the factors such as composition of dietary fat, age, gut environment, feeding regimen, concentration of divalent elements such as calcium and magnesium might affect the fat assimilation leading to lowered digestible energy value of fats.

Wiseman (1984) reported that the constituents of fats which did not contribute to subsequent dietary energy value included moisture and unsaponifiable content. A difference of 10 per cent in apparent metabolizable energy of a fat (included at 5 per cent level) making a difference of approximately 1 per cent in the apparent metabolizable energy of a compound diet was observed by him.

Bourdon *et al.* (1987a) suggested that incorporation of oils and fats in the feed, improved its dietary energy value beyond that which was predictable from simple addition of individual energy values. They observed that the fats and oils had beneficial effect upon the utilization of the other constituents of the diet and their dietary energy values were influenced considerably by the level of saturated fatty acids such as palmitic and stearic acids.

Bourdon *et al.* (1987b) gave the digestible energy values as 7900, 7900 and 7500 kcal/kg, for animal fats, lard and tallow, respectively, for pigs.

Cheeke (1999) reported that the fats and oils contained about 2.25 times as much digestible energy as carbohydrates and because saturated fatty acids were absorbed less efficiently, fats high in saturated fatty acids usually had a somewhat lower digestible energy value than oils.

2.1.6 Use of fat in sow diets

Seerley *et al.* (1978) reported that feeding of rendered animal fat to sow prior to parturition could affect the composition of colostrum, milk and pig carcasses, also appeared to decrease the quantity of body lipids utilized during a 72 d fast, and helped to insure adequate energy for pigs prior to birth and increased the energy reserves.

Fowler (1981) said that the lactating sow is a supremely competent mammal, able to convert dietary nutrients into milk with a very high gross efficiency of over 50 per cent for the utilization of dietary energy.

The feeding of lipids in late gestation and lactation provided opportunities for increased quantity and quality of milk and improved conditioning, rebreeding and longevity of sows in the breeding herd (Seerley, 1984).

Cheeke (1999) suggested that so long as the diet was kept balanced with respect to other nutrients, fat could be fed at high levels to non-ruminants as diets with 20 to 30 per cent fat were found to be palatable and readily consumed by swine. Hence the upper limit of inclusion can be fixed by taking into consideration of feed manufacturing and handling problems and not by the animal acceptance. He reported that feeding of high fat diets for at least 7 days prior to farrowing to sows was found to increase the survival rate of baby pigs by increasing their energy reserves.

2.2 Energy requirements

O'Grady *et al.* (1985) stated that the heavier sows had a higher maintenance requirement and the increasing energy demand was reflected in the increasing daily feed intake with greater numbers of pigs weaned.

Whittemore and Morgan (1990) suggested that the energy and protein needs of sows should include those required for the development of gravid uterus, the developing mammary tissues and for lactation as it was a function of both potential supply and realized litter demand.

Pettigrew *et al.* (1993) reported that the dietary energy intake exerted a large influence on adipose tissue metabolism in the pregnant gilt and hence the restriction of energy during pregnancy (6.1 or 4.2 Mcal of ME/day) and during lactation (6.5, 11.5 or 16.5 Mcal of ME/day) diminished lipogenesis from glucose.

Under-feeding of energy during pregnancy is associated with lower body fat reserves at farrowing or at weaning and delayed onset of estrus with lowered conception rate (Dourmad *et al.*, 1999).

2.2.1 Energy requirement for gestating sow

Agricultural Research Council (1981) recommends a digestible energy (DE) requirement (MJ/d) for a sow weighing either 120 kg, 140 kg or 160 kg at mating with a low gain as 25.5, 27.6 and 29.7 and with a high gain as 29.8, 31.9 and 33.9 MJ/day, respectively.

Seerley (1984) observed that energy requirement was approximately 29.29 MJ per day during late gestation against the energy level recommended by NRC (23.72 MJ of ME per day).

Walach-Janiak *et al.* (1986b) estimated the energy costs of maintenance and of protein deposition in the body of pregnant gilts at 444 KJ ME per $kg^{0.75}$ and 65.4 KJ ME per gram, respectively.

Henry *et al.* (1987) recommended dietary energy level of 3000 kcal DE/kg feed at gestation.

Verstegen *et al.* (1987) concluded that a sow would require energy about one per cent of body weight as maintenance and in addition about 700 g a day to meet the requirements during pregnancy, provided that the environment did not alter maintenance.

Young *et al.* (1990) fed sows at gestation with diets containing different levels of energy (Low, Medium and High) and observed increased number of pigs born, born alive, the number at 21 day lactation, weight of piglets at birth, litter weight as the gestation energy level increased.

King and Brown (1993) reported that the nitrogen retention increased with each increase in energy intake at each stage of pregnancy and during early pregnancy the rate of nitrogen retention increased linearly with energy intake.

Dourmad *et al.* (1994) concluded that the energy level during pregnancy for optimal longevity was not easy to establish and optimal level in pregnancy was closely related to housing condition, reproductive performance and energy feeding level during previous lactation.

Dourmad *et al.* (1996) concluded that in high-producing modern multiparous sows, energy supply during gestation was a limiting factor for nitrogen retention and muscle weight gain and should be approximately 8,500 kcal digestible energy per day to ensure adequate restoration of body reserves.

National Research Council (1998) recommends the DE and ME contents of diet and DE and ME intakes and the feed intake for gestating sows as 3,400 kcal/kg, 3,265 kcal/kg and 6,290 kcal/day and 6,040 kcal/day and 1.85 kg/day, respectively assuming ME as 96 per cent.

2.2.2 Energy requirement for lactating sows

English *et al.* (1979) stated that under feeding of energy during lactation resulted in reduction in milk yield of sows. The desirable energy intakes during lactation varied according to the sow, the feeding level in the previous pregnancy, the environment and other factors.

O'Grady (1981) reported that sows on an average required 80 MJ DE/day to keep them in positive energy balance over three reproductive cycles including 42-day lactations. However, Seerley (1984) reported that sows require 66.94 MJ of DE per day for lactation.

Agricultural Research Council (1981) recommends a DE requirement (MJ/d) for 56 days lactation for a sow weighing either 140, 160, 180 or 200 kg at postpartum with high milk yield as 70.7, 72.7, 74.7 or 76.5 MJ/day and with medium milk yield to be 62.3, 64.4, 66.3 or 68.1 MJ/day, respectively.

Henry *et al.* (1987) reported that following the inevitable mobilization of body reserves (especially at the beginning of the lactation when appetite of sows was reduced), the lactating sow with 10 or more piglets should be fed *ad libitum* a standard diet with digestible energy level of 3100 kcal per kg. For smaller litters (less than 8 piglets) this level of feed was corrected by substracting 850 kcal DE (or 275 gm of feed of 3100 kcal DE/kg) per piglet. They opined that the recommended dietary energy level at lactation should be 3100 kcal DE/kg feed.

National Research Council (1998) recommends the DE and ME contents of diet, the DE and ME intakes and the feed intake for lactating sows as 3,400 and 3,265 kcal/kg, 17,850 and 17,135 kcal/kg and 5.25 kg/day, respectively, assuming ME as 96 per cent of DE.

2.3 Reproductive and productive performance of sow

Pettigrew (1981) observed that supplemental fat in sow diet during late gestation and lactation increased the milk production and fat concentration of colostrum and milk and thereby increased the pig survival rate. The mean piglet weaning weight appeared to be increased when the dietary supplemental fat concentration was atleast 8 per cent.

Lellis and Speer (1983) observed that the sows fed additional tallow gained more weight, gave increased milk fat as a percentage of whole milk (4.94 per cent vs 6.57 per cent). The total milk fat in gram observed per day was 258 vs 321. The efficiency of milk energy production from ME was greater for tallow fed sows (31.5 per cent vs 40.70 per cent).

Seerley and Ewans (1983) stated that the high fat diets enabled pigs to consume more energy when housed at temperatures above the thermoneutral range, but not in cooler conditions and this was believed to be due to the lower heat increment of fat than carbohydrate or protein.

Holness and Mandisodza (1985) stated that the addition of fat to the diet of sows had no effect on the percentage of piglets born alive, individual piglet birth weight or weight of the piglet at three weeks of age.

Babinszky *et al.* (1992) concluded that vitamin E level and type of dietary fat (sunflower oil or animal fat @ 5% level) in the diet of primiparous sows had no significant effect on their reproductive performance.

Black *et al.* (1993) reported that the ambient temperatures above the evaporative critical temperature of lactating sows lead to a reduction in food intake, milk yield and reproductive performance of sows and growth rate of piglets. They further stated that their performance could be improved by reducing the animal's heat production by decreasing the fibre content and increasing the fat content of the diet.

Dove and Haydon (1994) found that the number of pigs born alive and the average pig weight at birth were not affected by the addition of 12 per cent tallow. However, the sows fed the same diet during lactation had heavier pig and litter weights on day 21 than those fed the basal diet.

Wojick and Widenski (1993) observed that the sows fed at 21.5 per cent energy higher than the recommended standard (by the addition of animal fat) gained more weight during pregnancy, had a larger litter size at birth, higher average birth weight and greater live weight of the young at 42 days of age.

2.3.1 Influence of addition of animal fat on sow's feed intake

Boyd *et al.* (1978 and 1982) stated that the daily feed intake of lactating sows was reduced when they were fed diets containing supplemental fat because of the increased energy density of the diet.

Pollmann *et al.* (1980) reported decreased feed intakes, but similar metabolizable energy intakes as that of control sows, when sows were fed diets with 8 per cent added tallow.

Stahly *et al.* (1980) found that adding fat to the lactation diet increased the daily metabolizable energy intake but decreased the feed intake of sows.

O'Grady (1981) opined that a large number of factors influenced voluntary feed intake of lactating sow and those factors of importance were crude protein level in pregnancy, diet, high-ambient farrowing house temperature, system of feeding and energy density of the diet.

Seerley *et al.* (1981) reported no differences in feed consumption between sows fed control diet and test diets containing either 10 per cent added corn oil or 10 per cent added animal fat.

O'Grady *et al.* (1985) suggested that lactation feed intake might increase by 0.2 kg per suckling piglet per day.

Shurson *et al.* (1986) observed that the weekly feed intake and total feed intake were not affected by fat supplementation (10% animal fat) or season.

Kanis (1990) stated that the modern sows were genetically leaner than the sows in the past, and this high leanness was associated with low appetite.

Shurson and Irvin (1992) observed that there were no genetic line x diet interactions for feed intake. They also reported that the level of maternal performance had no effect on consumption of control or fat added diets.

Azain (1993) reported that during gestation, sows adapted readily to the high fat diets (containing long chain or medium chain triglycerides) and observed that sows consumed slightly more of the diet containing long chain triglycerides (22.7 kg) and medium chain triglycerides (23.0 kg) during the first week of lactation than the control diet (20.7 kg).

Dove and Haydon (1994) observed that the sows fed high-nutrient diet (containing 12% added tallow) had decreased feed intakes with increased daily crude protein and gross energy intakes compared with the sows fed basal diet.

Genest and D'Allaire (1995) fed sows with gestation and lactation diets containing respectively, one 1per cent or 4.5 per cent animal fat and observed that the feed intake at day 1 of lactation was around 5 kg but was lower for the subsequent 4 days and increased as the lactation progressed.

Koketsu *et al.* (1996) stated that the lactation feed intake was low immediately post-farrowing and increased as lactation proceeded, reaching a maximum in the second or third week.

Tritton *et al.* (1996) observed that the voluntary feed intake of sows during lactation was unaffected by lysine or digestible energy content of the diets containing tallow.

2.3.2 Predicted body weight changes of sow during gestation and lactation

2.3.2.1 Pregnancy anabolism

Lodge *et al.* (1961) reported that there was a consistent increase in rate of gain during the fourth week followed by a very consistent marked check around the sixth week of pregnancy.

Heap and Lodge (1967) observed that pregnant sows had more carcass muscle and less carcass fat than the non-pregnant animals at similar feed intakes.

Close *et al.* (1984) in a study to compare the body weight gain at two feeding levels (1.8 and 2.5 kg per day with 20 and 30 MJ ME, respectively) at three specific stages of gestation: 40 to 60 days (early), 60 to 80 days (mid) and 90 to 110 days (late), reported that the increase in body weight of the sows was directly related to the level of feed intake and was significantly higher for the pregnant animals.

Close *et al.* (1985) reported that the protein deposition was highest during mid-pregnancy and was relatively independent of level of feeding during mid and late pregnancy, while, fat deposition depended on the level of feeding. In late gestation the low level of feeding was insufficient to prevent the pregnant animals losing fat @ 140 g fat/d from maternal stores.

Walach-Janiak *et al.* (1986a) reported that during gestation, protein and fat deposition increased linearly with elevation of the amount of food per day and the protein and energy costs of 1 g protein deposited in tissues was higher in the products of conception (6.57 g digestible protein and 7.92 KJ ME) than in the maternal bodies (3.66 g DP and 4.84 KJ ME).

Walach-Janiak *et al.* (1986b) reported that the pregnant gilts deposited more protein in the whole body than their non-pregnant analogues. However, no effect of pregnancy was found on the deposition of fat in the body. The energy costs of maintenance and of protein deposition were estimated at 444 KJ ME/kg$^{0.75}$ and 65.4 KJ ME/g, while in non-pregnant animals the respective values equaled 424 KJ ME/kg$^{0.75}$ and 104.3 KJ ME per gram.

Noblet and Etienne (1987a) opined that the advancement of pregnancy was associated with an increase in protein deposition and heat production which resulted in a reduced energy and fat deposition. This additional loss of heat with advancement of pregnancy (0.53 KJ/kg W$^{0.75}$/d of pregnancy) was related to the changes in the composition (protein Vs fat) and localization (uterine Vs maternal tissues) of the energy gain and not due to the extra heat production arising from the pregnancy itself.

Walker and Young (1992a) reported that the rates of protein and lipid accretion in maternal tissue were reduced to differing extents with the advancement of pregnancy and hence, the estimates of the ratio of maternal protein to lipid in weight gain varied with stage of gestation, litter size and protein and energy intake.

Lapshin and Matyaev (1994) obtained an average daily body weight gain of 536, 557, 583, 608 and 620 g for five groups of pregnant sows upon feeding one of the five diets containing animal fat @ 64.6, 94.8, 124.9,155.1 or 184.8 g per day respectively, for109 days from the start of pregnancy.

Liao and Veum (1994) reported that the gilts fed the high energy diet (containing 22.24% lard) had a higher average daily gain and a greater average backfat thickness than the gilts fed the normal energy diet (containing 5.1% lard).

Cooper *et al.* (2001) reported that the total gestation body weight gain was affected by parity; sows of parities 1 and 2 gained 64 per cent more body weight than sows of parity 3, and within parities 1, 2 and 3+, a positive correlation existed between sow body weight gain gestation energy intake (r=0.40, 0.21 and 0.14 for parities 1, 2 and 3+, respectively). They reported that the gestation body weight gain was negatively correlated with lactation body weight changes, that is for every extra kilogram of body weight gain in gestation, resulted in a loss of 0.3 kg in lactation (R^2=0.22) and the gestation energy intake was correlated negatively with lactation body weight change (r = -0.19).

2.3.2.2 Lactational catabolism

2.3.2.2.1 Mobilization of tissue energy reserves of sow

The result of nutritional short fall in lactation to the needs for milk synthesis is the catabolism of body fat and body protein, both for the provision of work of energy and the supply of precursors for milk constituents (Whittemore *et al.*, 1988).

Walker and Young (1992b) reported that the mobilized protein energy to meet the needs of milk protein production reduced the requirement for non-protein energy and this body protein entered the available pool with a high efficiency (near 1.0) and was therefore used for milk protein more efficiently than the feed protein.

Revell *et al.* (1998) reported that the sows lost body reserves during the first two to three weeks of lactation to support milk production and thereafter, they started to recover. However, they observed that the remaining one to two weeks of a normal four week lactation was generally too short to compensate completely for the losses during the first two to three weeks.

Kim and Easter (2001) conducted comparative slaughter experiment and reported that at 21 day lactation the total amount of protein mobilized from carcass, gastrointestinal tract, liver and reproductive tract in sows increased by

3.85 kg as the litter size increased from 6 to 12 pigs. Thus an additional pig caused 641 g of protein to be mobilized from the sow's body tissues. Carcass contributed the greatest amount (600 g) to the tissue protein mobilization. Gastrointestinal tract and the liver mobilized 21 and 14 g protein, respectively, while the reproductive tract mobilized only 7.6 g of protein. However, the percentage of tissue protein mobilized from the reproductive tract was the highest (26%) among the four tissues (14, 20 and 15% for carcass, GIT and liver, respectively). No trend in tissue fat mobilization was detected as litter size increased from 6 to 12 pigs.

2.3.2.2.2 Body weights of sows at farrowing and at weaning and their lactation body weight losses

Lodge (1959) reported that there was a marked loss in weight during the first week of lactation, even on a high scale of feeding, when the milk yield was still relatively low, and subsequent weight changes during lactation appeared to bear little relation to the shape of the lactation curve.

Lodge *et al.* (1961) reported that there was an initial loss of 10 to 20 lb during the first week, followed during the second week by a period when weight remained almost constant and then the mean weight decreased steadily until the seventh or eighth week where there was either a check in the loss or a small gain in weight.

English *et al.* (1979) suggested that a sow should be allowed to gain between 10 and 15 kg live weight from one weaning to the next or from one farrowing to the next. This increase should help the sow to be in the same body condition as it matures and the sow should be mature at about the fifth litter.

Reese *et al.* (1982) added bleachable fancy tallow (IFN.4-07-880) in the sow gestation and lactation ration @ 225, 348 and 454 g to form low, medium and high energy diets, respectively. The tallow provided 21 per cent of the daily energy intake for the diets. The lactation body weight change of sows (kg) was found to be higher (–20.8) for those on low energy diet than those on high energy diet (-0.6).

Lellis and Spear (1983) observed that lactating sows gained more weight during lactation (7.8 kg) when fed diets containing 15 per cent supplemental tallow than those fed diets with 27 per cent dextrose (1.6 kg).

Wilson and Pettigrew (1984) reported that the sows fed supplementary animal fat during late gestation and lactation were in a better body condition at weaning than the control sows, as determined by the body weight and backfat measurement.

Shurson *et al.* (1986) reported that the sow weight loss from farrowing to 28 day of lactation was unaffected either by season (summer or winter) or by diets (basal diet or basal diet with 10% added animal fat).

Henry *et al.* (1987) explained that during lactation the energy costs were associated with synthesis of the constituents of milk. For a mean daily milk production of 6-7 kg, the amount of energy cost was 7000-8000 kcal (1050-1150 kcal/kg). As a consequence of the high level of energy costs during lactation, high producing sows were unable to consume sufficient food to meet the costs even under *ad libitum* feeding conditions. Hence,they predicted a body weight loss of 10-25 kg during lactation.

King (1987) estimated the daily loses in lactation to be .1 kg of body weight and 0.3 mm backfat thickness.

Dourmad (1991) reported that there was a positive relationship found between body weight gain during pregnancy and weight loss during lactation. He suggested that the predicted muscle weight loss during lactation was related to pregnancy feeding levels whereas predicted fat weight loss was affected by level of feed intake during lactation.

Shurson and Irvin (1992) reported that the sow weight and backfat loss during lactaticn for high producing sows were not affected differently because of feeding diets containing supplemental animal fat. They suggested that the reduction in weight loss observed may be a result of higher total energy intake levels during lactation (383.1 Vs 347.3 Mcal of ME) and less body condition at farrowing.

Tokach *et al.* (1992) in a regression approach to assess quantitatively the influence of lysine and ME intake during lactation on yield of milk components found that the sow body weight and backfat losses were predominantly controlled by ME intake and the decreasing ME intake increased both sow body weight and backfat losses.

Dove and Haydon (1994) reported that addition of 12 per cent tallow to the lactation diet did not affect the sow body weight loss and backfat loss.

Genest and D'Allaire (1995) observed that the sows which were fed in wet form twice a day with a gestation diet containing 1 per cent animal fat and a lactation diet containing 4.5 per cent animal fat gained more weight and backfat during gestation and lost less weight during lactation than those fed diets in the dry form.. They also reported that during the first week of lactation, most sows gained weight, but thereafter lost weight, with the rate of weight loss reaching a peak during the last week of lactation.

Van den Brand *et al.* (2000) observed that the body weight loss of sows from day 6 to day 20 of lactation was higher in sows fed at low level compare with those fed at high feeding level (12.3 Vs 7.0 kg), whereas, the sows fed the fat rich diet (containing 8% tallow) lost more weight than sows fed the starch-rich diet (containing 17.8% corn starch) (10.9 Vs 8.4 kg).

Kim and Easter (2001) reported that the sow body weight loss during the 21 day lactation linearly increased when the litter size was increased from 6 to 12. There was an additional 1.92 kg weight loss as litter size increased by one pig during the 21day lactation.

2.3.3 Litter size

Matte *et al.* (1992) recognized that the most appropriate criteria used to assess sow productivity is the number of piglets born and/or weaned per year or throughout the breeding lifetime of the sow. They further stated that any improvement in the sow productivity must be associated with an increase in the frequency of farrowing.

Shurson and Irvin (1992) observed that the total number of pigs born, born alive, and alive after transfer, at 21 day and at weaning were greater for Duroc sows selected for leanness than the control sows.

Zou *et al.* (1992) opined that the efficiency of sow productivity was very often measured by the number of piglets produced and weaned per year.

2.3.3.1 Litter size at birth

Legault *et al.* (1975) stated that the breeding herd productivity was typically measured in terms of pigs weaned per sow per year and it had two determinants: pigs weaned per litter and litters per sow per year.

Seerley (1984) reported that the sows fed 0.18 kg/d or 0.27 kg/d of animal fat had more piglets born alive when compared to those sows fed diet containing corn starch.

Wilson and Pettigrew (1984) reported that the sows fed extra energy (8 MJ DE/d) as tallow for 10 days pre-partum had 34 per cent reduction in stillborn piglets (from 4.24 per cent for control fed sow to 2.8 per cent for sows fed animal fat supplement).

Walach-Janiak *et al.* (1986b) reported that the level of feeding had no effect on the litter size, or on the chemical composition of the gestation products.

Azain (1993) reported that there was no difference in number of live pigs at birth or in stillborn pigs among the sows fed medium chain or long chain triglycerides. However, beginning on day 1 of lactation and continuing through weaning, the number of pigs per litter was greater in the medium chain triglycerides fed group relative to the control.

Xue *et al.* (1993) reported that the herd, parity, month of the year and lactation length significantly affected total born and born alive litter sizes, total born per sow per year and born alive per sow per year and they observed that the longer lactation lengths were associated with higher subsequent litter sizes.

Lapshin and Matyaev (1994) obtained a litter size of 8.3, 8.9, 10.3, 10.1 and 9.1 at farrowing, respectively for sows fed 64.6, 94.8, 124.9, 155.1 and 184.8 g animal fat from the start of pregnancy to 109 days of pregnancy.

Farmer *et al.* (1996) reported that litter size at birth and percentage of stillbirth were not affected by addition of 3 per cent animal fat in the gestation diet of sows.

Cooper *et al.* (2001) reported that the total number of pigs born and pigs born alive per litter were affected by parity. Sows in first parity produced fewer piglets than those of parity 2 or 3+. They also reported that the litter size was positively correlated with total sow gestation body weight gain ($r = 0.41$) and every kilogram of total sow body weight gain in gestation corresponded to an extra 0.14 piglet born and 0.04 piglet born alive, which resulted in 50 g of additional litter weight at birth.

2.3.3.2 Litter size at weaning

English *et al.* (1979) reported that by reducing the age at weaning by one week, an extra of 0.1 piglet of a litter or about one extra pig was obtainable per sow per year, but at the same time suggested that reductions in age at weaning must be very carefully considered.

Lapshin and Matyaev (1994) obtained litter sizes (at 56 days weaning) of 6.7, 7.5, 8.9, 8.7 and 7.6, respectively for the sows fed 64.6, 94.8, 124.9, 155.1 or 184.8 g animal fat per day from the start of pregnancy to 109 days of pregnancy.

Tritton *et al.* (1996) observed that the litter size at weaning was unaffected by increasing the dietary digestible energy content from 12.6 to 15.1 MJ DE/kg by adding tallow in the lactation diets of sows as an energy source.

2.3.4 Sow body weight at farrowing and at weaning

Shurson and Irvin (1992) observed that the sow weight at farrowing was not different between the C (control) and S (selected for leanness) lines for Duroc sows, but weight loss was two-fold greater for S-line sows than for C-line sows during the 39 day lactation period. They also observed no differences for sow weight at farrowing, sow weight at weaning and lactation weight change for Duroc sows fed either a diet containing 10% corn oil (F) or control diet (N). They reported that the Landrace sows fed diets F and N, however had similar weights at farrowing, but those fed diet added with corn oil tended to weigh more at weaning and lose less weight during lactation than did the sows fed control diet.

Van den Brand *et al.* (2001) observed the average body weight of the sows after farrowing to be 170 kg and the lactational body weight loss to be 22 kg which was calculated to be 13 per cent of the body weight at farrowing.

2.3.5 Quantity and quality of colostrum and milk produced by sow

English *et al.* (1979) said that the milk yield could be improved by improving nutrition in the preceding pregnancy or in the lactation itself. However, higher the food intake in pregnancy, the lower the appetite in the following lactation. Therefore, they suggested that it was preferable to avoid over-feeding during pregnancy so as to improve the appetite of the sow in lactation and to allow her to meet the demands for milk production mainly from the food consumed during lactation rather than largely from body reserves deposited in pregnancy.

The piglet is born with little available fat stores and poor gluconeogenic capacity, and most piglets consume considerable colostrum during the initial 24 hour after birth to remain in energy balance (Hartmann *et al.*, 1984). They also reported that the piglets are born essentially agammaglobulinemic and are totally dependent on maternal antibodies in colostrum for their immune defense. Therefore, they suggested that the components of colostrum and milk that are of particular concern for the neonate are the high energy content, proteins, protective maternal antibodies, other disease resistance factors, and growth factors.

Close and Cole (1986) stated that the important factors that could influence milk quality and quantity were litter size, the nutritional state of the animal (in terms of energy and protein intake) and other factors of minor importance were breed, age and weight of the sow.

King *et al.* (1999) reported that the nutrient intake by the sow during lactation was insufficient to meet the needs of milk production and this nutrient shortfall resulted in the catabolism of body protein and body fat to supply the precursors for milk constituents.

Kim and Easter (2001) reported that the protein efficiency from milk to litter weight gain was 72 per cent.

According to Nielsen *et al.* (2001) the piglets must be big and uniform at weaning, for which the sow must have a high and uniform milk yield in all the productive mammary glands. They found a positive correlation between mammary gland size and milk yield (expressed by piglet weight gain) in the sow.

2.3.5.1 Yield of colostrum and milk by the sow

English *et al.* (1979) stated that the sow milk yield gradually rose to reach a peak at about three weeks after farrowing and thereafter declined steadily to reach a low level by eight weeks. They reported that the sow with

10 piglets should produce 5 litres of milk daily or at the start @ 20 ml of milk at each hourly suckling.

Boyd *et al.* (1982) determined the effect of feeding diets supplemented with tallow (0 or 8%) and choline chloride (220 or 770 mg/kg diet) prior to parturition (on day 100 of gestation to parturition) and during lactation on the preweaning pig performance and reported that the mean milk yield was 9.44 kg/d for sows receiving tallow and 8.72 kg/d for sows receiving the control diet. They, therefore, concluded that not only the sows produced greater concentration of milk solids and fats but the total quantity of milk constituents available to the offsprings was increased.

Coffey *et al.* (1982) observed that the milk yield at day 14 of lactation was increased approximately 30 per cent by the addition of animal fat (@ 8%) to the basal diet which was fed from day 109 of gestation to 21 day lactation.

Lellis and Speer (1983) fed two groups of sows with one of the two experimental diets containing either 27 per cent dextrose (D) or 15 per cent tallow (T) from 105 day gestation to 21 day lactation and observed that the milk yield increased from day 4 to 11 but did not differ between diets.

Noblet and Etienne (1989) reported that the neonatal growth in pigs was primarily dependent upon the milk production of sows and the sows suckling 10 piglets attaining an acceptable preweaning growth rate of 220 g/d would produce in an excess of 10 kg of milk each day of lactation.

Dove and Haydon (1994) reported that the crude protein concentration of milk was not affected by the diet energy density (containing 12% tallow). They suggested that the better litter response may probably be related to increased milk production or increased milk energy levels.

Farmer *et al.* (1996) reported that milk yield of sows on day 29 of lactation tended to be greater (8.8 kg/day) in sows fed a diet containing 3 per cent added animal fat at gestation than those fed a conventional diet (8.0 kg/day).

Toner *et al.* (1996) studied milk yield of sows nursing 6, 7, 8 or 10 piglets and observed a significant linear relationship between litter size and milk yield.

Van den Brand *et al.* (2000) observed no difference in the milk production or milk energy output per day, when the sows were fed two types of diets one rich in fat (8% tallow) and the other rich in starch (17.8% corn starch).

Kim and Easter (2001) estimated the milk yield from the NRC model using initial sow weight, weight loss during lactation, litter size, and litter weight gain. The milk production increased by 64.9 kg as litter size increased from 6 to 12 pigs during a 21 d lactation, which amounted to 10.8 kg per pig.

2.3.5.2 Composition of colostrum and milk produced by sow

Sow's milk contains 53 to 73 g protein, 46 to 52 g lactose, 73 to 88 g fat, 7.7 to 10.9 g ash and 5.4 MJ gross energy per kg (Elsley, 1971).

Malm *et al.* (1976) reported that the utilization of sources of polyunsaturated fatty acids, such as corn oil, in the diet of gilts resulted in lower serum colostrum and milk vitamin E levels than those fed lard.

Boyd *et al.* (1978). observed that the addition of animal fat (20% stabilized tallow) to provide 3843 kcal of ME/kg to the diets of sow during gestation increased fat content of colostrum, compared to those fed the control and corn starch diets (8.94% Vs 5.57%, 6.77% respectively), however, this increase was not sustained throughout the lactation. They also reported that administration of tallow immediately following parturition increased milk fat for the entire lactation period in comparison to the controls (10.04 Vs 8.10 g).

Sood and Giand (1979) postulated that the voluminosity of the casein micelle increased as the solvation increased without the loss of protein. Their observations showed that casein micelles of sow's milk were solvated 17 per cent more than that of the average cow's milk. The importance of solvation in sow milk might be that solvation influences protein retention time in gut slowing the rate of digestion and absorption (that is, the lower the solvation, the greater the retention time). Thus the piglets of crossbred sows whose milks had the lowest solvation ratios, were heavier at weaning.

Boyd *et al.* (1982) reported that throughout lactation period, sows fed the tallow supplemented diet (@ 8%) produced milk with higher concentration of total milk solids (22.15%) and fat (14.9%) than that of the control group (21.37% and 12% respectively). Milk protein content averaged over the lactation period was lower for sows receiving tallow. However, the depression appeared to be related to the samples because values for control and fat treatment groups were similar on days 9 and 18.

Coffey *et al.* (1982) observed that feeding animal fat to sows from day 109 of gestation to 21 day of lactation increased the per cent total lipids in milk. There were no treatment differences in milk crude protein, lactose, total lipids and solids not fat percentages and pH values. Vitamin A content of milk was increased by lipid feeding during lactation.

Lellis and Speer (1983) observed that the addition of 15 per cent tallow to the gestation and lactation diets of sows increased the milk fat as a per cent of whole milk (6.57 Vs 4.94%); or total g/day (321 Vs 258) and also the efficiency of milk energy production was greater for tallow fed sows (40.7 Vs 31.5%).

Shurson *et al.* (1986) observed that the sows receiving a lactation diet containing 10 per cent added animal fat had heavier litters at 21 day lactation and they concluded that this was primarily due to the 13 per cent increase in the estimated milk yield and the higher fat concentration of milk consumed by the pigs.

Le Dividich *et al.* (1991) opined that colostrum was the efficient route for acquisition of fat for the supply of energy to the pig during the first day after birth.

Babinszky *et al.* (1992) reported that an addition of vitamin E along with animal fat in the pregnancy diet increased the colostral vitamin E and the vitamin E content of milk than the sunflower oil combination in the gestation diet.

Shurson and Irvin (1992) upon adding 10 per cent added animal fat to the basal diet for feeding on 105 day of gestation of Landrace and Duroc sows found that Landrace sows produced milk higher in protein content than the Duroc sows. They also found that feeding fat increased milk fat content in both breeds.

Tokach *et al.* (1992) in a regression approach to assess quantitatively the influence of lysine and ME intake during lactation on the yield of milk components found that the lysine and ME intakes were interactive in their influence on milk protein, fat, energy, and total yield except lactose, demonstrating that the amount of lysine required to maximize milk production increased as the ME intake increased.

Zou *et al.* (1992) suggested that composition of colostrum and milk should not be a major limiting factor for the survival and growth of the piglets born to Meishan x Yorkshire crossbred gilts.

Azain (1993) reported that feeding long chain triglycerides resulted in an increase in total lipid and a shift in the ratio of polyunsaturated and saturated fatty acids of milk. In contrast, feeding medium chain triglyceride resulted in a decrease in milk lipid and a non significant decrease in polyunsaturated and saturated fatty acids (not significant, $P>0.1$) and a slight decrease in polyunsaturated and saturated fatty acids. They also observed that relative to the control sows, feeding medium chain triglyceride caused a five fold increase in content of medium chain fatty acids in the milk.

Le Dividich *et al.* (1994) suggested that a realistic recommendation of colostrum intake during the first postnatal day would be approximately 290 g/kg body weight and calculated that the available energy supplied by colostrum would meet 60 per cent production in typical birth environment conditions of 18 to 21°C.

Mills *et al.* (2000) reported that an increase in colostral or milk fat would provide improved piglet performance (in terms of piglet survivability, piglet growth rate and piglet weaning weight).

Van den Brand *et al.* (2000) when comparing the sows fed either fat rich (8% tallow) or starch rich (17.8% corn starch) diet during the 21 day lactation, found that the sows fed fat rich diet produced milk with a higher concentration of dry matter (20.2 Vs 19%) and protein (5.5 Vs 5.2%) and a lower lactose concentration in comparison with sows fed the starch rich diet. They also observed an interaction between feeding level and diet composition. With high level of feeding, sows fed fat rich diet produced milk with 1.5 per cent higher fat and 0.61 KJ/kg higher energy concentrations than the sows fed starch rich diet, but no effect of diet composition was found with the low feeding level.

2.4 Digestibility trial

2.4.1 Estimation of digestibility by indicator method

Yen *et al.* (1983) suggested that 4N HCl insoluble ash may be used as a natural indicator for estimating apparent nutrient digestibility in pigs, especially at younger ages.

Jongbloed *et al.* (1991) used HCl insoluble ash at the level of 0.5 g/kg feed and chromic oxide at 0.5 g/kg feed for the estimation of nutrient digestibility in pigs. They observed that coefficient of variation in the concentration of chromic oxide was halved in both feeds and faeces when it was added at 0.5 g/kg whereas the coefficient of variation for HCl insoluble ash marker was twice in feeds and lower in faeces.

Moughan *et al.* (1991) conducted digestibility experiments by the total collection method and by using chromic oxide and acid insoluble ash as faecal markers in young growing pigs. They found that total faeces collection gave significantly higher apparent digestibility coefficients compared to chromic oxide indicator method for dry matter, organic matter and gross energy. There were no significant differences in apparent nutrient digestibility determined by total collection of faces or by using acid insoluble ash marker.

Jagger *et al.* (1992) suggested titanium dioxide at a rate of 1 g/kg feed as the most appropriate marker for the determination of ileal and faecal apparent digestibility values in the pig.

Leeuwen *et al.* (1996) evaluated chromic oxide and HCl insoluble ash as markers for the determination of apparent ileal dry matter and crude protein digestibility of rations fed to pigs and reported that chromic oxide was more suitable as a marker than HCl insoluble ash.

2.4.2 Digestibility values of nutrients as affected by the addition of animal fat to the standard rations

Boenker *et al.* (1969) determined the digestible and metabolizable energy values of rendered fat. They observed that the added fat appeared to have little effect on the digestibility of various dietary components and the animal fat that was 88 per cent digestible was estimated to contain 8200 kcals DE/kg.

Lellis and Speer (1983) observed that the urinary nitrogen excretion and energy retained were higher for tallow (included at 15%) fed sow (19 Vs 17.8 Mcal/d). They also observed that the tallow did not affect calcium absorption or retention but increased urine and milk calcium, but the apparent absorption of phosphorus was increased by tallow (57.8 Vs 48.3%) and urinary excretion was also higher.

Jannsen and Carre (1985) observed an increase in the digestibility of added fat when the fibre content was increased by adding sunflower seed meal or alfalfa meal in the diet, but a decrease in digestibility of fat when the increased fibre content of the basal ration was based on wheat bran and thus the fibre of wheat bran seemed to have a negative effect on the digestibility of added fat.

Low (1985) reported that the digestion of dietary fibre increased during gestation and lactation.

Kemp *et al.* (1987) reported that either high feeding level (1.35 x maintenance) or low feeding level (1.1 x maintenance) did not significantly affect the digestibility of dry matter, protein and energy and their digestibility coefficient values were 0.79, 0.74 and 0.79 respectively for both levels of feeding.

Jones *et al.* (1992) reported a decrease in the apparent overall digestibility of lard but an increase in the apparent overall digestibility of soy oil and tallow following the addition of soy lecithin (10% added fat) to pig's diets.

Grandhi (1994) observed that feeding supplemental fat during the post weaning period had a beneficial effect on fat absorption and energy retention in both first and second parity sows. He further stated that the absorption and retention of nutrients during the post weaning period might have been influenced by the fluctuations in blood metabolites associated with milk resorption during the preweaning period.

Lapshin and Matyaev (1994) fed 5 groups of sows with 5 different diets containing 64.6, 94.8, 124.9, 155.1 or 184.8 g animal fat per day, from the start of pregnancy to 109 days and observed that the digestibilities of nutrients, especially those of fat and nitrogen free extract, increased as pregnancy advanced and the level of fat addition was increased.

Liao and Veum (1994) reported that the gilts fed the high energy diet (containing 22.24% lard) had higher apparent dry matter and fat digestibilities, higher ME retained/d, higher DE and ME as percentages of GE than the gilts fed normal energy diet (containing 5.1% lard), but similar nitrogen retained, nitrogen digestibility, and nitrogen retained/nitrogen intake for both energy treatments eventhough nitrogen intake/day was lower for gilts fed the high energy diet.

Overland *et al.* (1994) in a study to know the effect of lecithin as an external emulsifier on apparent ileal and overall digestibility of crude fat, fatty acids and other dietary nutrients, used two levels of lecithin (0 and 0.24%) and rendered animal fat (at 0 and 6% level) and found that the ileal and overall digestibility of crude fat and total fatty acids increased with the inclusion of rendered fat in diets. Furthermore, rendered fat increased the apparent ileal and overall digestibility of C14:0, C16:1 and C18:1 fatty acids and the apparent overall digestibility of C18:0 fatty acid.

2.5 Litter performance

2.5.1 Litter weight

English *et al.* (1979) reported the average birth weight of stillborn piglets, of all live born piglets, of live born piglets dying before weaning and those of surviving piglets to be 0.96, 1.24, 1.0 and 1.32 kg, respectively, and said that the piglets which died were of lighter weight category.

Coffey *et al.* (1982) reported that feeding animal fat (at 8% level) or corn starch in a basal diet from109 day of gestation until farrowing and then only the basal diet upto 21 day of lactation, found to have no effect on the average pigs and litter weights at birth or on days 7, 14 and 21 of lactation.

Shurson *et al.* (1986) obtained an average birth weight of 0.15 kg higher for pigs born during summer than those born in winter. They also observed that the sows receiving fat diet (containing 10% added animal fat) had heavier litters at 21 day and reported that this was primarily due to the 13.1 per cent increase in the estimated milk yield and the higher concentration of the milk.

Azain (1993) reported that feeding either medium chain or long chain triglycerides to pregnant sows had no effect on the average pig weights at birth or at any time through weaning.

Lapshin and Matyaev (1994) reported the birth weights of pigs as 1135, 1228, 1310, 1357 and 1224 g from the pregnant sows fed diets containing 64.6, 94.8, 124.9, 155.1 or 184.8 g animal fat per day for 109 days of gestation from the start of pregnancy.

Farmer *et al.* (1996) reported that the birth weight of pigs was unaffected by the addition of 3 per cent animal fat, in the gestation diet.

Cooper *et al.* (2001) observed that the weights of litters born to parity 1 sows were lower than the weights of litters born to parity 2 or 3+ sows and the average piglet body weight at farrowing for parity 1 sow was 130 g lighter than piglets form parity 2 or 3+ sows.

2.5.1.1 Litter weight at weaning

Boyd *et al.* (1982) reported a trend toward slightly heavier pigs (6.35 Vs 6.11 kg) and litters (153.97 Vs 151.94 kg) after 21 d lactation period in the group of nursing sows receiving 8 per cent tallow supplemented diets.

Reese *et al.* (1982) added bleachable fancy type (IFN 4-07-880) tallow in the sow gestation and lactation diets @ 225, 340 and 454 g to form low, medium and high energy diets, respectively. They observed that the sows fed low energy diet weaned lighter weight pigs than the sows fed high energy diet. They recorded an average piglet weaning weight of 6.4 kg at 28 days of age.

2.5.1.2 Growth rate of piglet

Hafez (1963) opined that the growth rate of piglet before weaning was dependent on birth weight, age at weaning and genotype of the piglet, and the milk production, mothering ability and age of the sow.

English *et al.* (1979) reported that the piglets were entirely dependent for their nutrition, in the first two to three weeks of life on milk of their dam and therefore, suggested that the growth rate could be improved in this early period of life with increase in the sow milk yield.

Stahly *et al.* (1980) concluded that the dietary animal fat feeding to sows did not influence the growth rate or survival rate of pigs from birth to weaning or from weaning to market weight.

Lellis and Speer (1983) reported that the pigs from sows fed 15 per cent tallow had numerically higher rate of gain than those of the sows fed 27 per cent dextrose.

King (1986) showed a significant difference in the growth rate of piglets prior to weaning which had resulted mainly from a significant quadratic response to sow food intake in the growth rate of piglets from 21 to 28 days of age.

Dyck *et al.* (1987) and Fraser *et al.* (1992) were of the same opinion that the lower average daily gain in piglets suckling the rear teats of multiparous sows might be because these glands had not been used in the previous lactation leading to a decrease in productivity.

Noblet and Etienne (1987b) reported that concentration 3.7 g of sow milk resulted in 1 g of piglet live weight gain.

Thompson and Fraser (1988) reported that the litters with low weight during the first days of life continued to have low gains later in life.

Castren *et al.* (1991) reported that on an average the weight gain of piglets between the first and second hour after birth was 45 g, while it was 25 kg between the second and third hour. The weight gain in later periods per piglet was about 20 g per suckling. Piglets that were heavier at birth (>1500 g) gained significantly more weight than the lighter piglets (<1300 g) during the first 24 h.

Van der Lende and De Jager (1991) found that the average preweaning growth rate differed between litter types and suggested that this was entirely due to differences in average litter size at birth.

Walker and Young (1992a) observed that for the days 1 to 41 of lactation, piglet growth rate was curvilinearly related to age. They suggested that the additional variation in growth rate was accounted for by the variation in milk intake.

Azain (1993) observed that the total litter weight of sows fed a diet containing medium chain triglyceride to be 22 kg and reported that it was 18 per cent greater than that of litters from the sows fed either the control or long chain triglyceride diets ($P<0.05$).

Van den Brand *et al.* (2000) reported that on day 20 of lactation, body weight of piglets from the sows fed at high feeding level was higher than those of sows fed at low feeding level (5.9 Vs 5.3 kg) due to a higher average daily gain between day six and day 20 (258 Vs 217 g per day respectively).

Kim and Easter (2001) reported that the average daily litter weight gain increased linearly as the litter size increased from 6 to 12. They observed an additional 2.92 kg litter weight gain during the 21 to 28 lactation as the litter size increased by one pig. They also reported the average daily weight gain of nursing pigs to be 154 g regardless of litter size.

Nielsen *et al.* (2001) reported that there was no relationship between in mammary gland size and piglet growth rate in the primiparous sows. However, they observed that in the multiparous sows, growth rate was highest in the piglets suckling the front teats and intermediate in those suckling the rear teats.

2.5.2 Influence of animal fat feeding to sow on the piglets tissue energy reserves and piglet performance

2.5.2.1 Piglets tissue energy reserves

Seerley (1984) opined that the energy reserves in newborn pigs had been relatively difficult to increase by their dietary manipulation because of the slower depletion of piglet's liver glycogen during the first 12 hours after birth. They therefore, suggested that fat feeding to the sow immediately prior to farrowing had the possibility of improving the piglet's energy reserve status, and thereby their survivability.

Close and Cole (1986) reported that they could obtain only inconsistent responses with attempts to increase the energy reserves of piglets at birth, and thus their prospects of survival, by the manipulation of nutrition of sow in late pregnancy through the supplementation of the normal diets with fats and oils. They also concluded that there was no sound basis for making practical recommendations for the inclusion of fats and oils in terms of increased energy reserves.

King *et al.* (1999) stated that amount of sow's milk suckled by the piglets was helpful in building up the body fat which could serve both as an energy store and as an insulation layer.

Van den Brand *et al.* (2001) reported the piglets of sows fed fat-rich diet (containing 8.1% tallow) at a high feeding level had higher body fat energy concentrations than that for piglets of sows fed the starch-rich diet (containing 17.8% corn starch). The slaughter study revealed that body ash and body protein tended to be lower in piglets of sows fed the fat-rich diet than those of sows fed starch-rich diet (0.8 g/kg and 3.9 g/kg, respectively.

2.5.2.2 Piglet performance after weaning to marketing

Boyd *et al.* (1978) determined the effect of the dam's gestation – lactation diets (containing 20 per cent stabilized tallow) upon subsequent performance of pigs fed an identical diet to approximately 95 kg body weight, using the average daily gain, feed intake and feed efficiency as response criteria. They observed that all the pigs in each of gestation – lactation subclass whether fed tallow or not responded similarly with no significant differences observed for the productive traits tested.

2.5.3 Survivability and mortality of piglets

English *et al.* (1979) reported that the preweaning deaths of piglets were caused by multiplicity of social, husbandry and health factors interacting with each other. They also suggested, that the great majority of piglet losses took place in the first few days of life.

2.5.3.1 Piglet survivability

Kim *et al.* (1966) and Bourne *et al.* (1973) were of the same opinion that the piglets could not obtain immunoglobulins, which play an important role in building up the immunity, through placenta and thus initially they relied on passive immunity derived from the sow's colostrum for survivability in their early period of life.

Edwards (1972) said that the survival and satisfactory growth of piglets were highly dependent on the colostrum and milk produced by the sow. They also reported that starvation and scours directly accounted for a major portion of early piglet mortality and indirectly contributed to crushing as a result of lowered viability.

Boyd *et al.* (1978) reported a non significantly higher piglet survival rate (81.6%) at 14 days of birth for the sows fed tallow during lactation thatn those sows which were not fed tallow (79.2%). They also observed a higher (53.4%) survival rate among those piglets which were weighing <1000 g of sows fed tallow than those of sows not fed tallow (43.3%).

Hendrix *et al.* (1978) reported that the long-term survival of pigs was related to the amount of serum immunoglobulins acquired through the colostrum within the hours immediately after birth.

Pollmann *et al.* (1980) reported that the addition of tallow in sow diet did not significantly improve the survival rates of piglets. They observed that the survival rates pooled over for three reproductive cycles were approximately 8 per cent higher for sows fed alfalfa and there was no significant improvement by tallow feeding.

Boyd *et al.* (1982) reported that the survival of piglets at 21 d lactation in relation to the number of pigs born alive per litter, did not differ significantly between litters from sows receiving tallow (94%) and litters from the sows not receiving tallow (92.5%).

Gieslak *et al.* (1983) reported the piglet survival rates of live born pigs to 21 d of age to be 84.9 per cent and 79.1 per cent, respectively, for the sows receiving a basal diet containing 15% dietary animal fat and the control diet. The piglet survival data analysed by them by logistic regression indicated that a 15% increase in dietary fat increased the odds of piglet survival at all birth weights.

Holness and Mandisodza (1985) reported that due to the addition of animal fat (lard) @ 0.2 kg per day to the basal diet of sow, there was a significant increase in the piglet survival rate. They, but, observed that there was no indication of a greater effect of added fat in the sow's diet on the survival of smaller piglets. They had also reported that the major benefits of additional fat in the sow diet were effected in utero rather than via an increase in the quality of the sow's milk.

Azain (1993) reported that percentage of survival (birth to weaning) was improved with feeding medium chain triglyceride (MCT), when compared with the control or the long chain triglyceride (LCT) fed groups. The overall 10% improvement in survival of litters from the sows fed MCT resulted in more than one pig per litter reduction in mortality. There was no significant benefit of the

LCT supplemented diet on piglets survival. The overall analysis of survival rates in various birthweight categories revealed an improved survival of higher weight pigs in litters from both fat diets (LCT and MCT added diets). Survival of pigs weighing less than 900 g at birth was 32% (6 of 19) in control litters and was increased to 53% (16 of 30) and 68% (15 of 22) in litters from LCT and MCT fed sows, respectively.

2.5.3.2 Piglet mortality

Fahmy and Bernard (1971) concluded that the mortality of live-born piglets was 15 to 20 per cent before weaning because of the competition in litters, showing large variation in litter weight. They also said that the variation in litter weight affected the possibility of the piglet to regularly consume adequate amounts of milk during the first days of life leading to hypothermia and weakness, making the piglets being easily crushed by the sow.

English *et al.* (1979) enumerated that the important causes of death in liveborn piglets were starvation (43%), crushing (18%), congenital abnormalities (12%), extremely weak at birth (9%), suffocation during farrowing (6%), primary infection (6%) and miscellaneous (including savaging, born alive but suffocated in afterbirth – 6%). They also reported piglet mortalities of 17.7% and 27.2% for uniform litters and variable litters, respectively.

England (1986) reported a piglet mortality of 30 to 40 per cent for those pigs weighing less than 1 kg.

De Pasille and Rushen (1989) reported that the limited colostrum availability and consumption as early as possible during farrowing cause high mortality and poor growth rate of piglets.

Florou-Panere *et al.* (1994) reported the mortality of piglets from sows fed conventionally processed animal fat, specially processed mixture of animal and vegetable fat or without added fat as 6.56, 2.44 and 6.61 per cent at weaning and 8.20, 3.25 and 9.09 per cent until slaughter.

Genest and D'Allaire (1995) obtained a litter size of 10.29 at farrowing and 9.96 at weaning for the sows fed a gestation diet containing 1% added animal fat and a lactation diet containing 4.5% added animal fat. They observed an average piglet mortality of 3.2 per cent and they reported the major causes of death to be crushing and complications following castration.

Farmer *et al.* (1996) reported that the number of meals per day per sow affected survival of pigs from 48 h post partum to day 7. The percentage of mortality was 5.8 and 1.7 for pigs in litters of sows fed four times and twice daily, respectively.

2.6 Effect of season on the sow performance

Dove and Haydon (1994) observed that the sows farrowing in cool season consumed more feed during lactation than did sows farrowing in the warm season while the number of live born pigs and birth weight of the pigs were not affected by season of the year. They also reported that the sows farrowing in the cool season had heavier pigs and litters on d 21 of lactation and lost less body weight than did sows farrowing in the warm season

2.7 Economics of gain

English *et al.* (1979) estimated that, to improve average piglet birth weight by only 0.1 kg, an extra 100 kg of sow food would have to be given in pregnancy and hence the cost/benefit ratio of increasing feed intake in pregnancy to improve mean piglet birth weight and piglet survival would depend on the cost of extra food required and the value of the extra piglets likely to be saved.

In a study to know the effect of plane of feeding during pre-partum and lactating stages on mothering ability and subsequent conception in sows, the observations indicated that a low plane (10 per cent decrease of CP and DE with reference to NRC level, containing beef tallow as energy source) of feeding during gestation and lactation was not conducive to the sow and litter and reduced the economic efficiency with regard to litter output. However, switch over to high plane (10 per cent increase of CP with reference to NRC level, containing beef tallow as energy source) of feeding from 84 days of gestation till weaning found to be most efficient with respect to litter output and economy (Joseph Mathew, 1992).

Xue *et al.* (1993) said that the nursery phase was typically the cheapest and therefore, facility costs per weaned pig will be less as the numbers of litters and number of pigs weaned annually from each farrowing crate increase.

Cheeke (1999) reported that although feeding high fat diets (containing 7.5 to 15% rendered animal fat) had a favourable effect on baby pig survival, it is not always economical.

Materials and Methods

3. MATERIALS AND METHODS

3.1 Experimental Animals

Thirty-two Large White Yorkshire sows at late gestation (100 days of gestation) belonging to the Centre for Pig Production and Research, Mannuthy, Kerala formed the experimental animals.

3.2 Experimental design

The experimental animals were divided into four equal groups of eight replicates each into a completely randomized block design. The four groups of experimental animals were randomly allotted to one of the four dietary treatments (T1, T2, T3 and T4). All the animals were maintained on their respective diets from late gestation to weaning (56-day lactation).

3.3 Experimental house

The present experimental study was conducted in the farrowing shed of the Centre for Pig Production and Research, Mannuthy, Kerala. Throughout the experiment, all the animals were housed on concrete floor with no access to soil or vegetation. The pregnant sows at late gestation were shifted to the farrowing shed and each was housed individually in a separate farrowing pen from late gestation to sixty days after farrowing. The sows were kept in the farrowing shed for four more days after fifty-sixth day of weaning for conducting the digestibility trial. The leftover feed if any and the faecal matter were removed and the farrowing sheds were washed thoroughly in the morning and in the evening. Clean drinking water was provided *ad libitum* daily. All the animals were maintained under standard identical managemental conditions throughout the experimental period.

3.4 Experimental diets

The sows were fed a standard diet containing 3300 kcal DE /kg and 18 per cent crude protein. Rendered animal fat was added to the standard ration at different levels so as to form four experimental diets. The four different dietary treatments were

T1 - Control diet (standard ration)

T2 - Control diet + 5% rendered animal fat

T3 - Control diet + 10% rendered animal fat

T4 - Control diet + 15% rendered animal fat

The standard methods (AOAC, 1990) were followed to estimate the chemical composition of the experimental diets. The per cent ingredient composition and chemical composition of the experimental diets are given in Tables 1 and 2, respectively.

Table 1. Ingredient composition of the standard ration

Ingredients	Per cent
Yellow maize	50.00
Rice polish	16.50
Wheat bran	10.00
Soy bean meal	12.00
Unsalted dried fish	10.00
Mineral mixture[a]	1.00
Salt	0.50
Indomix-A+B2+D3+K[b]	25 g per 100 kg feed mixed
Indomix-BE[c]	25 g per 100 kg feed mixed

a Keyes Mineral mixture without salt (KSE Ltd., Irinjalakuda)

Ingredients: Calcium- 24.0%; Manganese- 0.15%; Phosphorus-12.0%; Copper-0.5%; Magnesium- 6.5%; Iodine- 0.03%; Sulphur- 0.5%; Iron- 0.5%; Cobalt- 0.02%; Fluorine (max) - 0.04%; Zinc - 0.38%; Moisture - 4% and Acid insoluble ash (max)- 2%

b Indomix- A+B2+D3+K (Nicholas Piramal India Ltd., Mumbai)
Composition per gram: Vitamin A- 82,500 IU; Vitamin B2- 50 mg; Vitamin D3- 12,000 IU; Vitamin K - 10 mg

c Indomix-BE (Nicholas Piramal India Ltd., Mumbai)
Composition per gram: Vitamin B1- 4 mg; Vitamin B6- 8 mg; Vitamin B12- 40 µg; Niacin- 60 mg; Calcium Pantothenate- 40 mg; Vitamin E – 40 mg

Table 2. Chemical composition of the standard ration[a]

Item	Per cent
Dry matter	89.24
Crude protein (N×6.25)	18.02
Ether extract	3.57
Crude fibre	8.01
Nitrogen free extract	58.25
Total ash	12.15
Acid insoluble ash	7.67
Calcium	1.63
Phosphorus	0.75

a Average of six values on dry matter basis

3.5 Feeding trial

Each sow was fed individually in a separate farrowing pen. The sows were fed twice daily (11.30 AM and 4.30 PM). They were offered standard ration @ 2 kg per day from late gestation to farrowing and 2.5 kg plus 200 g per piglet per day till weaning (56 days) and also during digestibility trial. The feeding scales for the sows at two different stages of reproduction (late gestation and lactation) are given in the Table 3. The piglets after one month of age were fed a diet containing 18 per cent crude protein @ 200 g per piglet per day upto 56 days of weaning. The standard ration and rendered animal fat were measured daily and were hand mixed at the time of feeding.

Table 3. Feeding scales for the sows at late gestation and lactation

Stage of reproduction	Quantity of feed and rendered animal fat fed per sow per day (kg)							
	T1		T2		T3		T3	
	Feed	Fat	Feed	Fat	Feed	Fat	Feed	Fat
Late gestation	2	-	2	0.1	2	0.2	2	0.3
Lactation*	2.5	-	2.5	0.125	2.5	0.25	2.5	0.375

* Feed allowance per day per sow was based on the number of live piglets suckled by the sow

3.6 Main items of observation

The records of daily feed intake of sows with litter were maintained throughout the experiment. The litter size, litter weight at birth and at weaning, postpartum and post-weaning body weights of sows and piglet mortality were recorded. The chemical composition of the standard ration, experimental diets and faeces were analysed and recorded. Digestibility coefficients of nutrients and the economic benefits of incorporation of rendered animal fat in the diets were calculated using the data obtained.

3.7 Digestibility trial

Digestibility trial was conducted in sows at the end of the experiment (on fifty-sixth day of weaning) to determine the digestibility coefficients of nutrients of the experimental diets by taking acid insoluble ash as the internal indicator.

Faecal grab samples, uncontaminated with urine and dirt were collected from different places of each pen at 6.00, 12.00 and 18.00 hours, during the period of three days of digestibility trial. The samples from each pen were mixed thoroughly and placed in double lined polythene bags, labelled and preserved in deep freezer for analysis. The samples of feed and faeces collected each day from each pen were pooled, respectively and sub-samples were taken and were analysed for proximate composition as per the standard methods (AOAC, 1990).

The digestibility coefficients of nutrients were calculated, taking the acid insoluble ash as internal indicator, using the appropriate formulae (Maynard *et al.,* 1979 and McDonald *et al.,* 1995).

3.8 Statistical analysis

The data obtained were analysed by the Completely Randomised Design (CRD) method as described by Snedecor and Cochran (1995).

Results

4. RESULTS

4.1 Litter size

The data recorded on litter size at birth and at weaning of sows maintained under four different dietary treatments T1, T2, T3 and T4 and the mean values are presented in Table 4 and the mean values are graphically represented in Fig.1. The average litter size of sows belonging to the groups T1, T2, T3 and T4 at birth were 9.6, 9.5, 10 and 9 and at weaning were 7.5, 7.5, 7.75 and 7.38, respectively.

4.2 Piglet weight

The data on mean piglet weight (kg) per sow at birth and at weaning, and the average piglet weight per group at birth and at weaning are presented in the Table 5 and the average values are graphically represented in Fig.2. The average piglet weights were 1.47, 1.40, 1.38 and 1.54 kg at birth and 7.96, 8.59, 8.90 and 8.95 kg at weaning for T1, T2, T3 and T4, respectively.

4.3 Body weight gain of piglets

The data on average daily weight gain (g) of piglets from birth to weaning with the mean values are presented in the Table 6 and the mean values are graphically represented in Fig.3. The average daily gain of piglets of sows under the treatment groups T1, T2, T3 and T4 were 115.8, 128.8, 134.0 and 132.3 g, respectively.

4.4 Postpartum and post-weaning body weights of sows

The recorded data on postpartum and post-weaning body weights (kg), the calculated weight loss of sows from lactation to 56 days of weaning and their mean values are presented in the Table 7. Their mean values are graphically represented in Figs.4 and 5, respectively. The average postpartum body weights of sows of T1, T2, T3 and T4 groups were 155.0, 125.0, 145.0 and 134.4 kg; of post-weaning were 134.6, 110.4, 133.0 and 123.0 kg; and of body weight losses were 20.63, 14.69, 12.19 and 11.40 kg, respectively.

4.5 Piglet mortality

The calculated average per cent mortality of piglets per sow is presented in the Table 8. The average per cent piglet mortality of T1, T2, T3 and T4 group sows were 21.10, 20.71, 21.24 and 16.72, respectively and are represented graphically in Fig.6.

The consolidated data on the performance of the sows and litters belonging to the four experimental groups are presented in Table 9.

4.6 Digestibility coefficients of nutrients

The per cent chemical composition of experimental diets and feces collected from the sows during the three days period of digestibility trial are presented in Tables 10 and 11, respectively. Data on digestibility coefficients of nutrients of the four experimental diets T1, T2, T3 and T4 are presented in Table 12 and are graphically represented in Fig.7. The average values of digestibility coefficients of dry matter of experimental diets T1, T2, T3 and T4 were 69.11, 70.65, 72.04 and 72.92; of crude protein were 86.27, 87.73, 87.49 and 88.10; of ether extract were 84.13, 89.49, 90.13 and 90.30; of crude fibre were 32.56, 28.79, 26.24 and 25.10 and of nitrogen free extract were 79.52, 80.29, 82.63 and 83.31.

4.7 Economics of gain

The experimental diet intake of sow and the feed intake of the litter with the cost of total quantity of experimental diet consumed by a sow and feed consumed by piglets are given in the Table 13. The cost benefit ratio of inclusion of rendered animal fat at different levels in the late gestation and lactation diets of sows is given in the Table 14. The cost : benefit ratio of the four treatment groups T1, T2, T3 and T4 were 1:2.36, 1:2.51, 1:2.54 and 1: 2.56, respectively.

Table 4. Litter size at birth and at weaning of sows fed different experimental diets

Replicates	Litter size							
	At birth				At weaning			
	T1	T2	T3	T4	T1	T2	3	T4
1	11	10	12	9	8	7	9	8
2	12	7	10	8	9	6	8	6
3	7	8	11	6	6	6	10	6
4	8	9	7	9	8	7	7	7
5	11	11	10	12	8	9	7	9
6	10	7	8	9	9	6	7	8
7	11	12	12	12	7	9	8	9
8	7	12	10	7	5	10	6	6
Average ± SE	9.6 ± 0.71	9.5 ± 0.73	10.0 ± 0.76	9.0 ± 0.76	7.5 ± 0.5	7.5 ± 0.57	7.75 ± 0.45	7.38 ± 0.46

Fig.1. Average litter size at birth and at weaning of sows fed different experimental diets

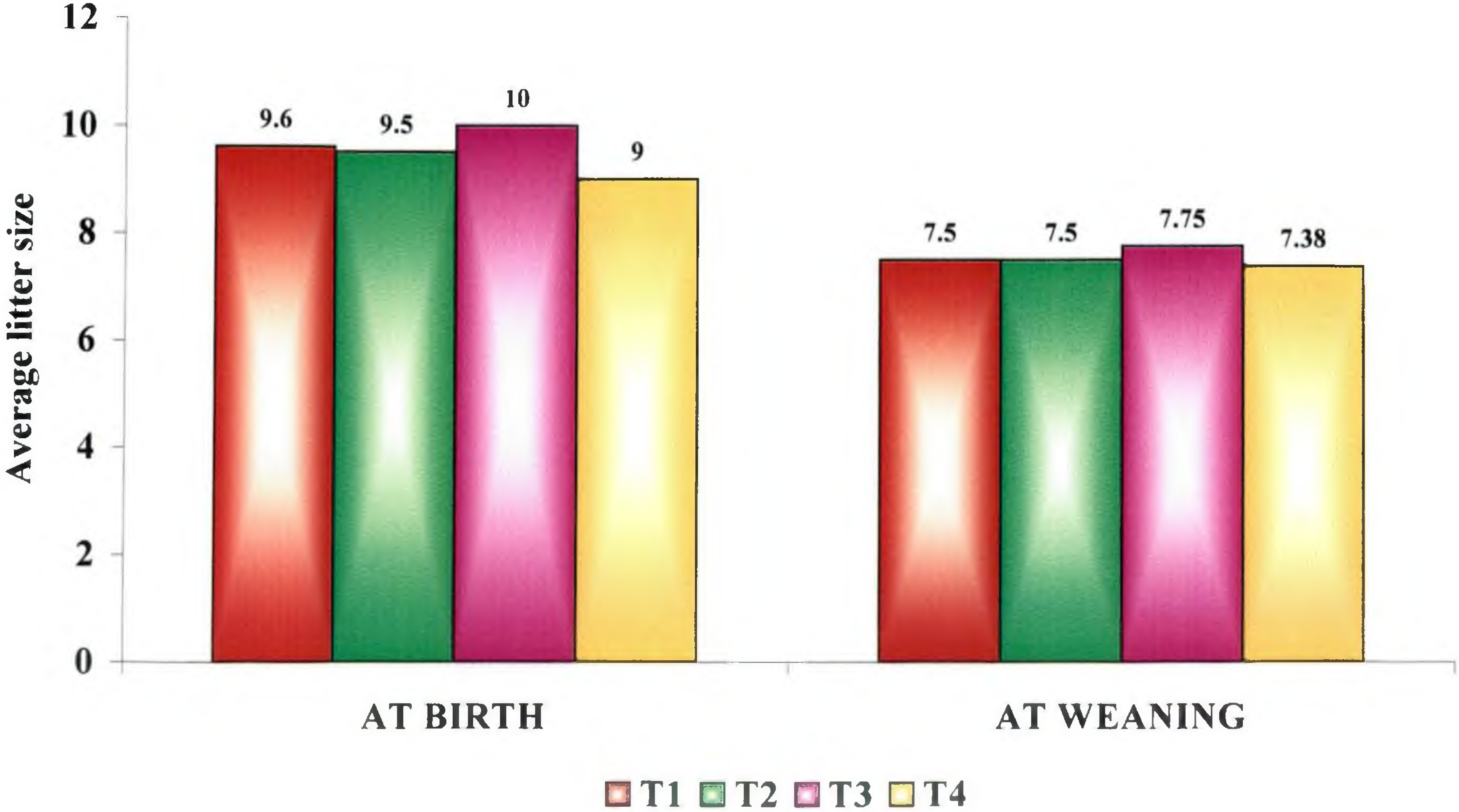

Table 5. Average piglet weight (kg) at birth and at weaning of sows fed different experimental diets

Replicates	Average piglet weight (kg)							
	At birth				At weaning			
	T1	T2	T3	T4	T1	T2	T3	T4
1	1.66	1.44	1.59	1.49	7.06	8.44	9.21	6.50
2	1.67	1.33	1.3	1.13	5.11	7.94	8.50	8.42
3	1.69	1.55	1.56	1.72	8.75	7.05	11.08	10.08
4	1.61	1.26	1.62	2.09	8.31	8.49	9.86	10.14
5	1.14	1.74	1.39	1.64	8.75	9.5	7.06	8.50
6	1.25	1.62	1.22	1.39	8.11	8.57	10.50	7.25
7	1.45	0.96	1.15	1.47	8.57	8.81	6.16	7.06
8	1.12	1.23	1.2	1.41	9.0	9.92	7.05	12.17
Average ± SE	1.47 ± 0.09	1.40 ± 0.09	1.38 ± 0.07	1.54 ± 0.1	7.96 ± 0.46	8.59 ± 0.57	8.90 ± 0.63	8.95 ± 0.68

Fig.2. Average piglet weight (kg) at birth and at weaning of sows fed different experimental diets

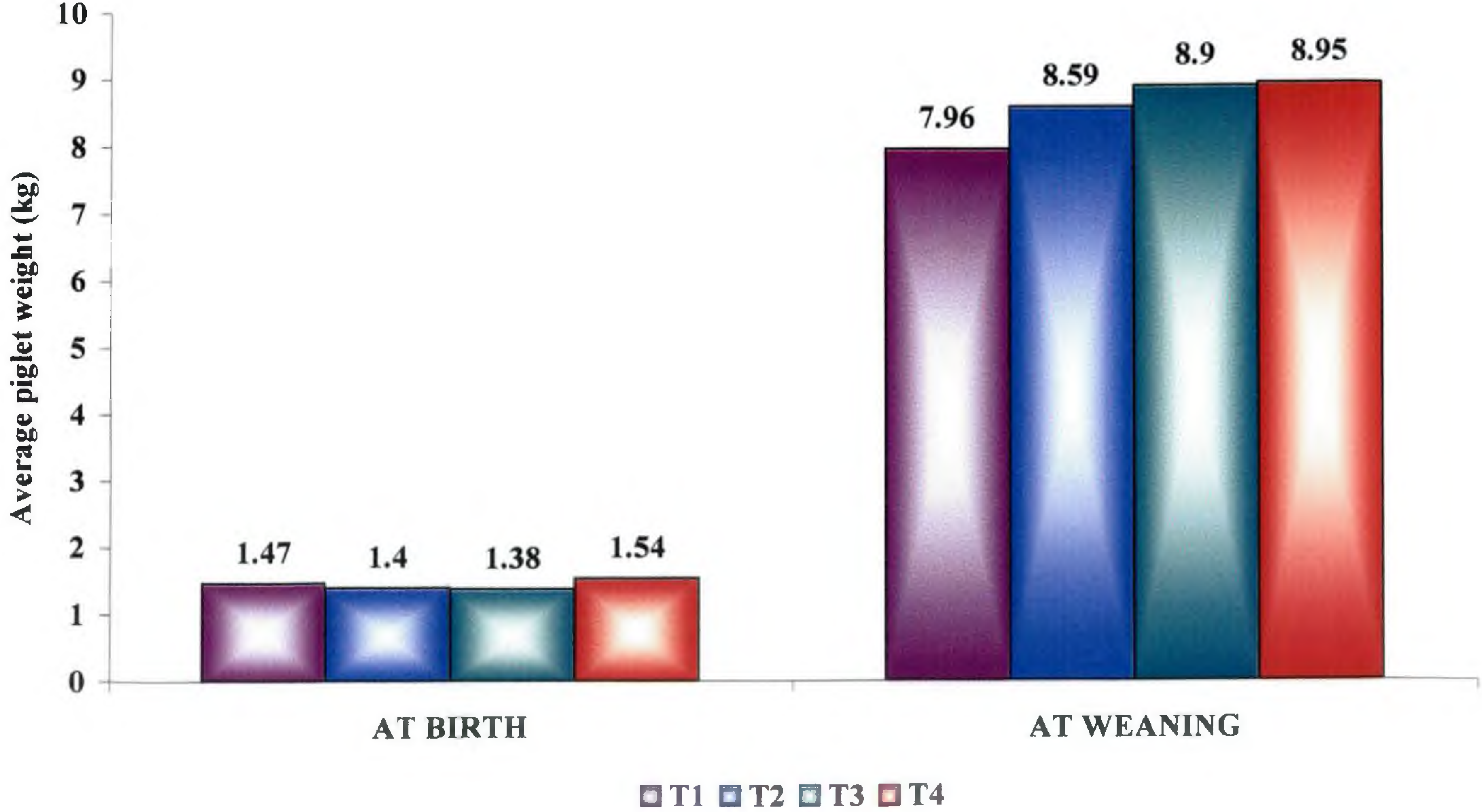

Table 6. Average daily gain (g) of piglet of sows fed different experimental diets

Replicates	Average daily gain (g)			
	T1	T2	T3	T4
1	96.43	122.3	138.8	89.46
2	61.43	118.6	129.5	130.2
3	126.10	98.04	170.2	149.3
4	119.60	122.68	153.6	143.8
5	135.90	144.80	95.0	122.5
6	122.50	131.3	158.6	104.6
7	127.10	136.80	92.9	99.82
8	140.70	155.7	103.9	192.1
Average ± SE	115.8 ± 9.11	128.8 ± 7.47	134.0 ± 10.7	132.3 ± 11.7

Fig. 3. Average daily gain (g) of piglets of sows fed different experimental diets

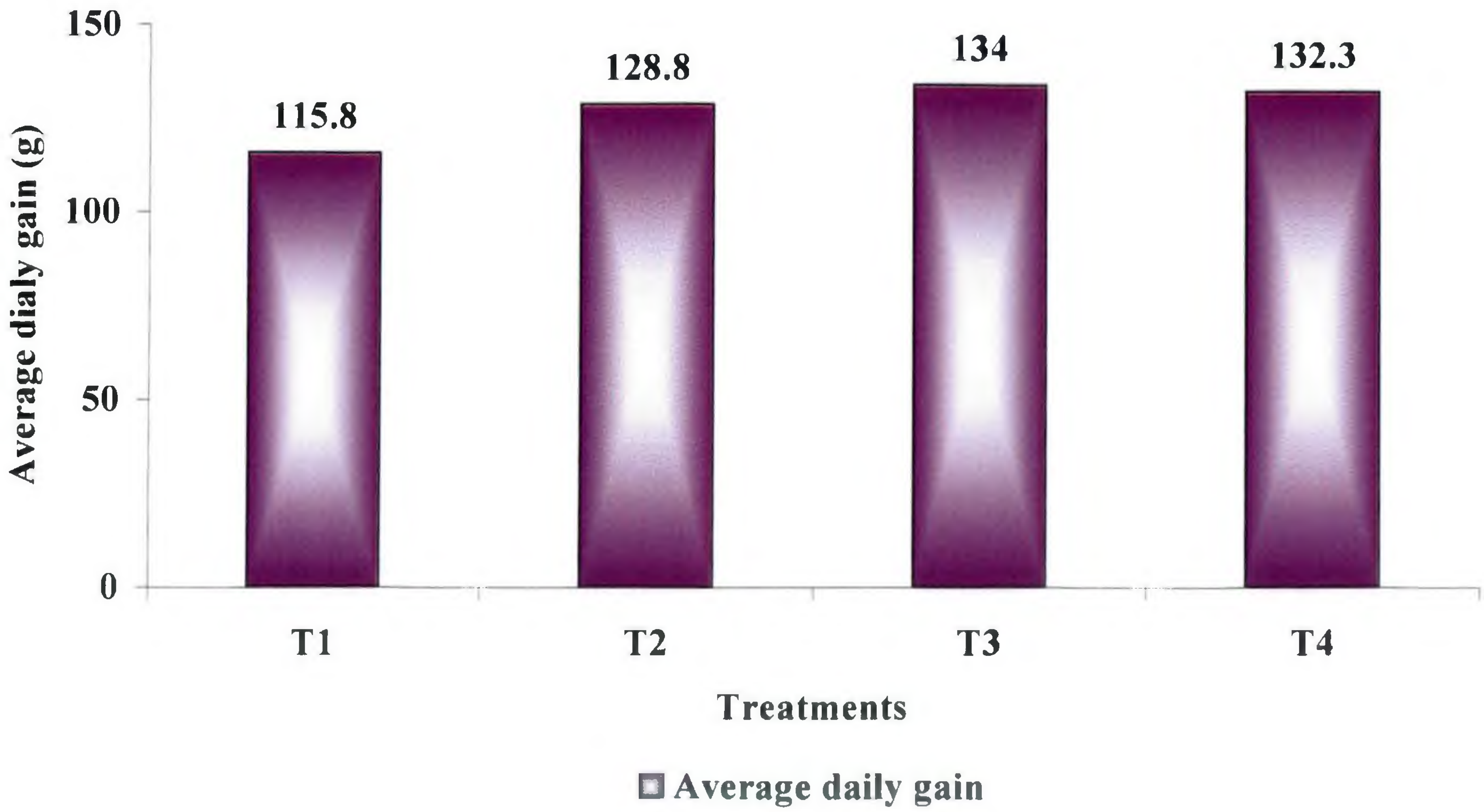

Table 7. Postpartum and post-weaning body weights (kg) of sows fed different experimental diets

Replicates	Postpartum body weight (kg)				Post-weaning body weight (kg)				Change in body weight (kg)			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
1	121	121	157	107	94	108	126	108	-27	-13	-31	+1
2	179	126	142	96	143	106	137	97	-36	-20	-5	+1
3	167	137	146	134	158	117	141	130	-9	-20	-5	-4
4	121	159	146	163	97	136	136	158	-24	-23	-10	-5
5	202	117	169	152	171	98	160	121	-31	-19	-9	-31
6	146	135	158	126	132	126	149	94	-14	-9	-9	-32
7	170	90	127	141	154	82	106	131	-16	-8	-21	-10
8	137	116	116	156	128	110	109	147	-9	-6	-7	-9
Average ± SE	155± 10.24	125± 7.07	145± 8.37	134.4± 9.85	134.6± 9.85	110.4± 5.87	133± 6.54	123± 8.04	-20.63± 3.61	-14.69± 2.31	-12.19± 3.24	-11.4± 4.67

+ Lactational body weight gain (kg)
- Lactational body weight loss (kg)

Fig.4. Average postpartum and post-weaning body weights (kg) of sows fed different experimental diets

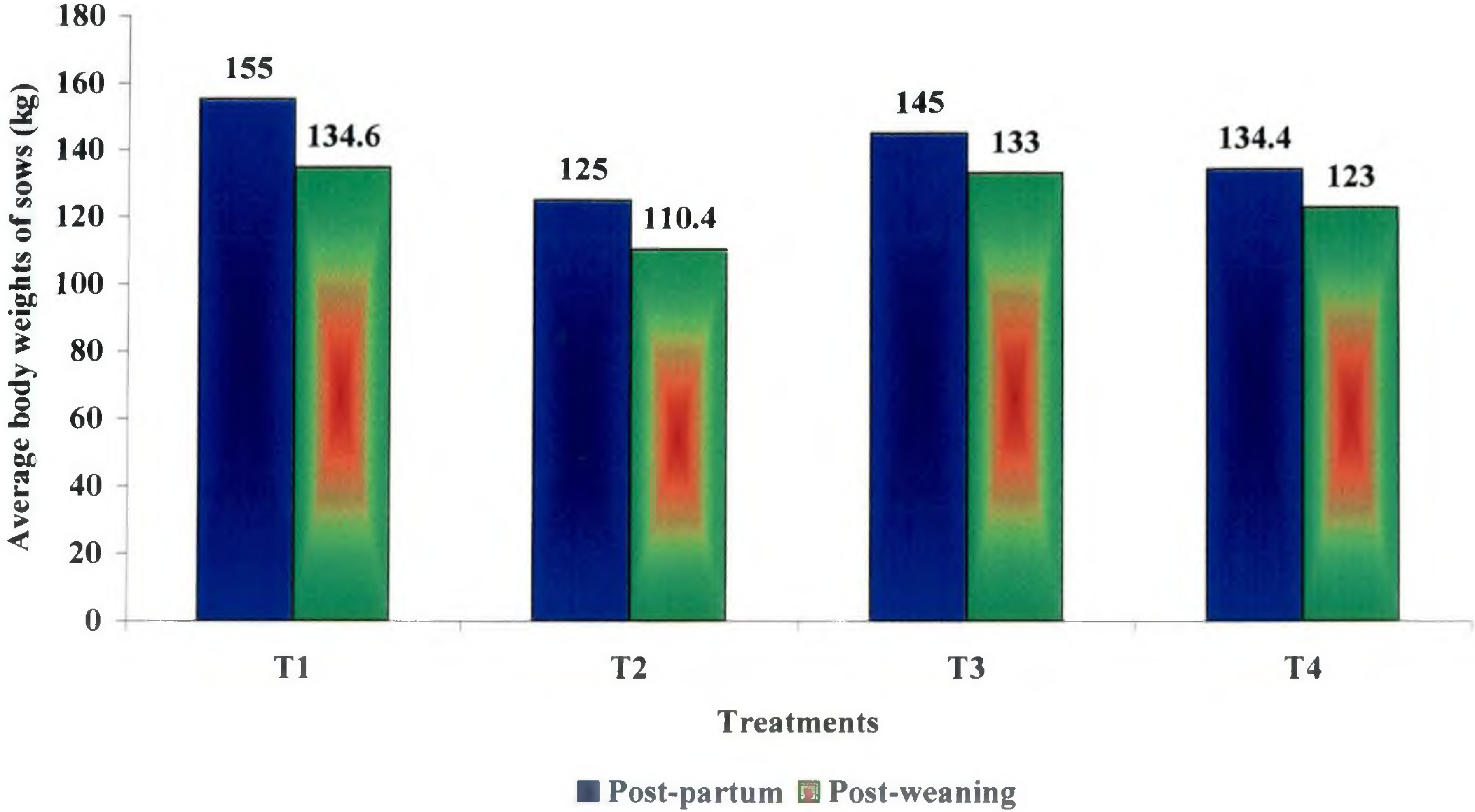

Table 8. Mortality (%) of piglets of sows fed different experimental diets from farrowing to weaning

Replicates	Mortality (%)			
	T1	T2	T3	T4
1	27.27	30.00	25.00	11.11
2	25.00	14.29	20.00	25.00
3	14.29	25.00	9.10	0.00
4	0.00	22.23	0.00	22.22
5	27.27	18.18	30.00	25.00
6	10.00	14.29	12.50	11.11
7	36.36	25.00	33.33	25.00
8	28.57	16.67	40.00	14.29
Average ± SE	21.1 ± 4.21	20.71 ± 2.03	21.24 ± 4.75	16.72 ± 3.23

Fig.6. Mortality percentage of piglets of sows fed different experimental diets

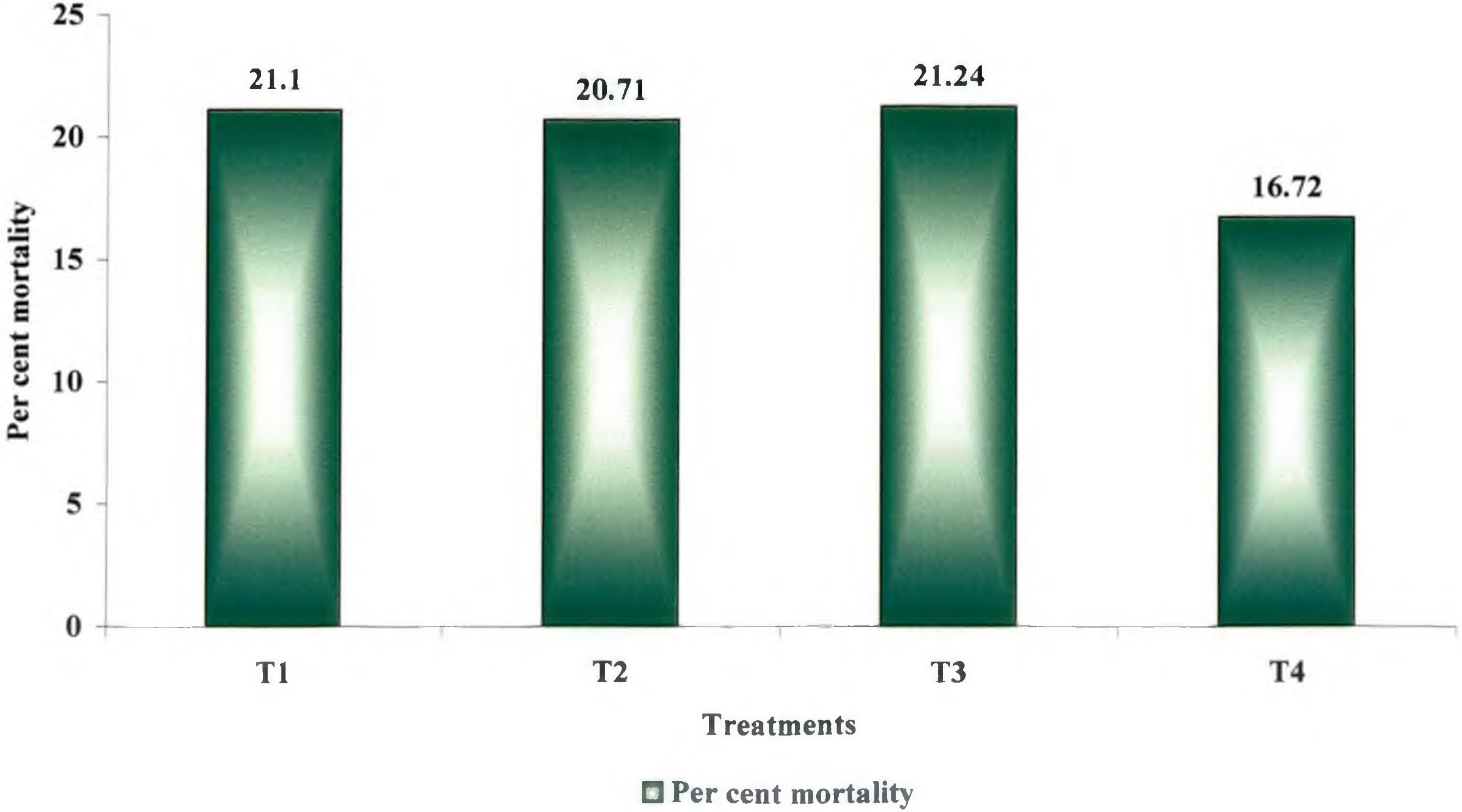

Table 9. Performance of the sows and litters belonging to the different experimental groups (Mean ± SE)*

Parameters	Treatments			
	T1	T2	T3	T4
Average litter size at birth**	9.6 ± 0.71	9.5± 0.73	10± 0.47	9± 0.76
Average litter size at weaning**	7.5± 0.5	7.5± 0.57	7.75± 0.45	7.38± 0.46
Average piglet weight at birth (kg)**	1.47± 0.09	1.4± 0.09	1.38± 0.07	1.54± 0.1
Average piglet weight at weaning (kg)**	7.96± 0.46	8.59± 0.57	8.9± 0.63	8.95± 0.68
Average daily gain by piglet (g)**	115.80± 9.11	128.8± 7.47	134± 10.7	132.3± 11.7
Average postpartum body weight of sow (kg)**	155.00± 10.24	125.00± 7.07	145.00± 6.04	134.40 ± 8.37
Average post-weaning body weight of sow (kg)**	134.6 ± 9.85	110.4 ± 5.87	133 ± 6.54	123 ± 8.04
Average lactation body weight loss of sow (kg)**	20.63 ± 3.61	14.69 ± 2.31	12.19± 3.24	11.4 ± 4.67
Average per cent mortality of piglets per sow**	21.1± 4.21	20.71± 2.03	21.24± 4.75	16.72± 3.23

* Mean of eight values
** Non significant (P>0.05)

Table 10. Chemical composition of experimental diets (%)*

Item	Treatments			
	T1	T2	T3	T4
Dry matter	88.12	92.55	92.40	92.00
Crude protein (Nx6.25)	17.90	18.01	17.99	18.06
Ether extract	3.90	9.87	13.27	16.56
Crude fibre	8.25	8.19	8.71	9.09
Nitrogen free extract	57.95	51.01	47.27	43.52
Total ash	12.00	12.92	12.76	12.77
Acid insoluble ash	7.10	7.77	7.59	6.52
Calcium	1.53	1.73	1.34	2.01
Phosphorus	0.72	0.70	0.73	0.95

* Average of eight values on dry matter basis

Table 11. Chemical composition of faeces of sows fed different experimental diets (%)*

Item	Treatments			
	T1	T2	T3	T4
Dry matter	20.04	16.61	18.71	20.08
Crude protein (Nx6.25)	7.98	7.52	8.02	7.86
Ether extract	2.06	3.53	4.67	5.93
Crude fibre	18.10	19.85	22.89	24.32
Nitrogen free extract	38.50	34.22	29.26	26.92
Total ash	33.36	34.88	35.16	34.97
Acid insoluble ash	23.06	26.45	27.05	24.06

* Average of eight values on dry matter basis

Table 12. Average digestibility coefficients of nutrients of the four experimental diets (Mean ± SE) #

Nutrients	Treatments			
	T1	T2	T3	T4
Dry matter*	69.11± 2.82	70.65± 2.75	72.04± 1.92	72.92± 1.73
Crude protein*	86.27± 0.73	87.73± 1.02	87.49± 1.08	88.10± 0.73
Ether extract**	84.13^{b}± 0.50	89.49^{a}± 0.75	90.13^{a}± 0.40	90.30^{a}± 0.59
Crude fibre***	32.56^{a}± 0.13	28.79^{b}± 0.28	26.24^{c}± 0.11	25.10^{d}± 0.28
Nitrogen free extract****	79.52^{c}± 1.34	80.29^{bc}± 1.32	82.63^{ab}± 0.42	83.31^{a}± 0.25

Mean of eight values
* Non significant (P>0.05)
** Significant (P<0.01)
*** Significant (P<0.001)
**** Significant (P<0.05)
a,b,c,d Means with different superscripts within the same row differ significantly

Fig. 7. Average digestibility coefficients of nutrients of the four experimental diets

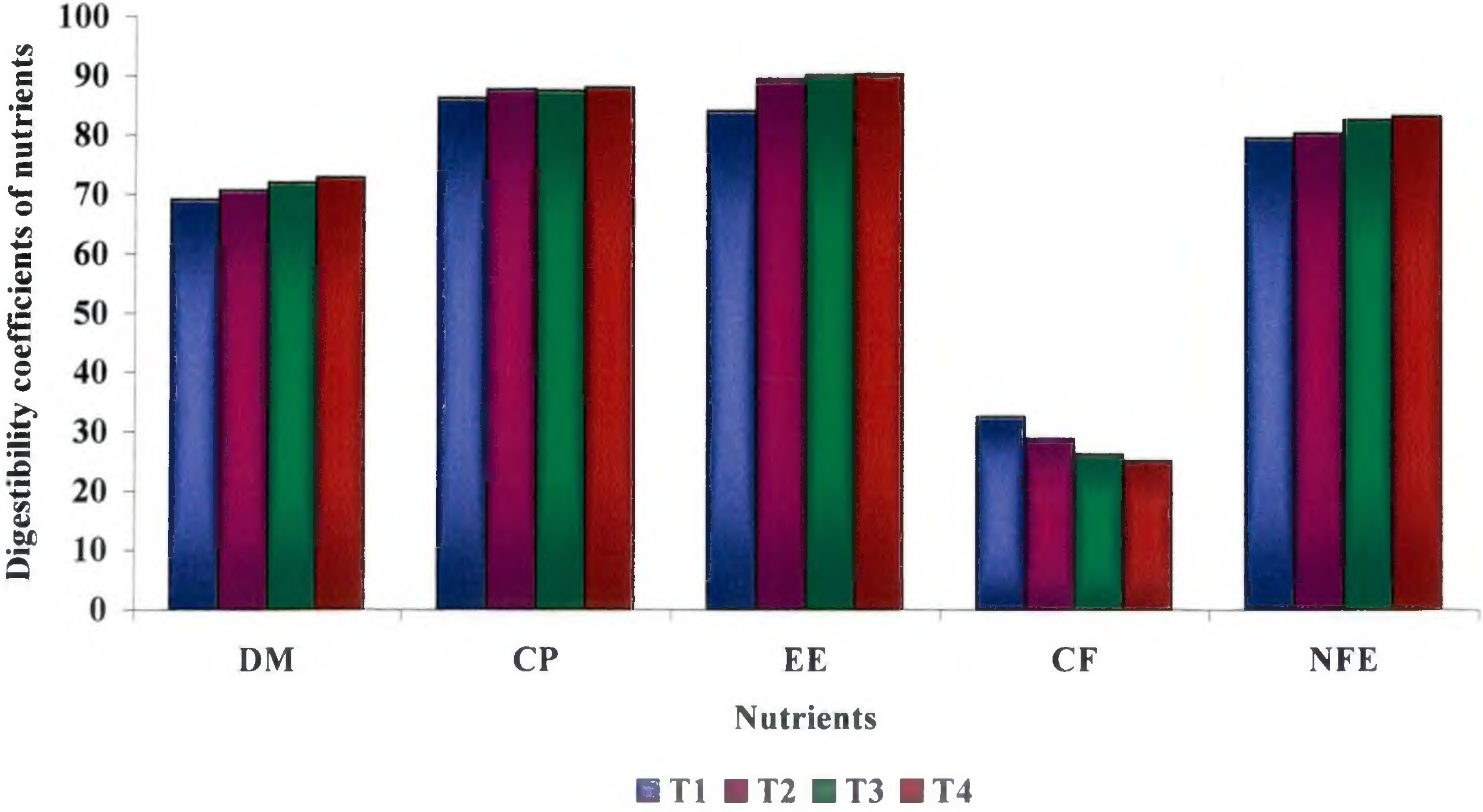

Table 13. Cost of experimental diets consumed by sows with litters of respective experimental groups

Item	Treatments			
	T1	T2	T3	T4
Average quantity (kg) of standard diet consumed by a sow for 71 days period	193.7	198.8	205.0	185.94
Cost (Rs.) of standard diet consumed by a sow @ Rs.6.82 per kg*(A)	1321.03	1355.82	1398.1	1268.11
Average quantity (kg) of rendered animal fat consumed by a sow for 71 days period	--	9.94	20.5	27.89
Cost (Rs.) of rendered animal fat consumed by a sow @ Rs.8 per kg (B)	--	79.52	164	223.12
Average amount (kg) of feed consumed by litter @ 0.2 kg per piglet per day for 26 days	39	39	40.3	38.38
Cost (Rs.) of feed consumed by litter @ Rs.7 per kg* (C)	273	273	282.1	268.66
Total expenditure on feed (Rs.) (A+B+C)	1594.03	1708.34	1844.2	1759.89

* Cost of feed ingredients is based on the rate contract fixed for the supply of various feed ingredients to the farm for the year 2001-02

Table 14. Cost benefit ratio of inclusion of rendered animal fat at different levels in late gestation and lactation diets of sows

Item	Treatments			
	T1	T2	T3	T4
Average litter size at weaning	7.5	7.5	7.75	7.38
Average piglet weight (kg) at weaning	7.96	8.59	8.9	8.95
Average litter weight (kg) at weaning	59.70	64.43	68.98	66.70
Cost (Rs.) of average litter weight produced per sow @ Rs.100 per kg live weight at weaning (A)	5970	6443	6898	6670
Average postpartum body weight loss per sow (kg)	20.63	14.69	12.19	11.14
Economic loss (Rs.) due to lactation body weight loss @ Rs.30 per kg live weight (B)	618.90	440.70	365.70	342.00
Cost (Rs.) of the experimental diet fed to a sow (C)	1594.03	1708.34	1844.2	1759.89
Gross profit (Rs.) [A-B]	5351.10	6002.3	6532.3	6265.00
Net profit (Rs.) [(A-B)-C] = D	3757.07	4293.96	4688.1	4505.11
Cost benefit ratio (D÷C)	1:2.36	1:2.51	1:2.54	1:2.56

Discussion

5. DISCUSSION

5.1 Sow Performance

5.1.1 Influence of feeding rendered animal fat to the sow on its feed intake

A perusal of the data presented in the Table 13 indicates that the average quantity of standard diet and rendered animal fat consumed by a sow for a period of 71 days (15 days prepartum to 56 days postpartum) were 193.7, 198.8, 205.0 and 185.94 kg and zero, 9.94, 20.5 and 27.89 kg, respectively for T1, T2, T3 and T4 groups. The average feed consumption (standardized for 71 days period) of the sows of T4 group was numerically lower than those of the remaining groups. This reduction in the average feed consumption (kg) is attributed to the difference in piglet mortality (as the extra amount of lactation diet fed to each sow per live piglet per day was curtailed when it lost piglets) and is not due to the rejection of the experimental diets by the sows, an expected effect which was not observed during the entire course of the study.

The observation on the average feed consumption in this study is supported by the inferences of Seerley *et al.* (1981), Shurson *et al.* (1986) and Tritton *et al.* (1996) who reported that there was no difference in the total feed consumption during lactation among the sows fed control diets and test diets containing added animal fat.

A reduced feed intake by lactating sows when fed supplemental animal fat, because of the increased energy density of the diet was reported by Boyd *et al.* (1978 and 1982); O' Grady (1981); Pollmann *et al.* (1980); Stahly *et al.*

(1980) and Dove and Haydon (1994). Farmer *et al.* (1996) and Azain (1993) reported an increased average feed consumption during gestation and lactation by the sows fed animal fat added test diets than those fed control diet.

5.1.2 Postpartum and post-weaning body weights and the lactational body weight loss of sows

The data on average postpartum and post-weaning body weights of sows and the average lactational body weight losses given in Table 9 reveals that there was no significant difference for average lactational body weight losses of sows between treatments (P>0.05). It is, therefore, suggested that the diet composition had not contributed to the difference between diets for influencing significantly the body weight of sows at farrowing within the short span of feeding trial from 100 days of gestation to farrowing and at 56 days of weaning. Hence, the difference in average post partum and post-weaning body weights of sows between treatments can be attributed to the random assignment of sows to the dietary treatments. The above observation is consistent with that of Shurson and Irvin (1992).

The sows of T2, T3 and T4 groups had a trend towards lower lactational body weight loss (14.69, 12.19 and 11.4 kg, respectively of T2, T3 and T4 groups) at 56 days of weaning compared to that of sows of control group T1 (20.63 kg). The above observation indicates a negative correlation between gestation body weight gain and lactation body weight loss which is agreeable with the statement of Cooper *et al.* (2001).

The rendered animal fat fed to sows of T2, T3 and T4 groups had maintained them in a better body condition compared to T1 group sows. The better body condition of the sows fed rendered animal fat can be due to the reduced mobilization of tissue energy reserves by the sows for the synthesis of milk constituents because of the increased availability of dietary energy and is supported by Whittemore *et al.* (1988) and Whittemore and Morgan (1990). But this is not in agreement with Van den Brand *et al.* (2000) who had reported that those sows fed fat rich gestation and lactation diet (containing 8% tallow) lost more weight during lactation than those fed starch rich diet (containing 17.8% corn starch).

Reese *et al.* (1982) recorded a lactation body weight change of –20.8, -12.1 and –0.6 kg, respectively, for the sows fed low, medium and high energy gestation and lactation rations containing 225, 348 and 454 g tallow, respectively. The data recorded on lactation body weight change for T1 group (-20.63 kg) and T3 group (-12.19 kg) in this study correspond with that of the above mentioned data for sows fed low and medium energy gestation lactation rations, respectively.

King (1986) reported 28 day lactation body weight loss as 9 kg for the first litter sows which consumed 5 kg of lactation diet per day containing 12.55 MJ DE/kg and 146 g crude protein and the observed data of present study is not consistent with the above reported data.

The observed lactation body weight losses in this study are falling within the range of 10 to 25 kg which was the predicted range of lactation body weight loss by Henry *et al.* (1987) for high producing sows having high level of energy costs during lactation.

The average lactation body weight losses were 22, 12.3 and 19 kg, respectively for a sow weighing 170 kg post partum (Van den Brand *et al.*, 2001) and for Duroc sows fed a diet containing 10 per cent corn oil and for Landrance sows fed a control diet (Shurson and Irvin, 1992). The values are comparable with the data obtained in the present study.

It is inferred from this study that the sows can be prevented from losing more body weight during lactation by the addition of rendered animal fat in their late gestation and lactation diets as there is a trend towards lower body weight reduction as the level of rendered animal fat increases.

5.1.3 Litter size at birth and at weaning

The average litter sizes of sows at birth were 9.6, 9.5, 10 and 9 and at weaning were 7.5, 7.5, 7.75 and 7.38, respectively for sows of T1, T2, T3 and T4 groups (Table 4). There was no significant difference (P>0.05) observed for the average litter size at birth or at weaning between the treatments (Table 9). There was no still birth observed during the entire course of the experiment in all the four treatment groups.

The sows fed T2 and T4 diets had a trend for fewer (P>0.05) total pigs born than those fed T1 and T3 diets. Though the sows fed T2 diet recorded non significantly lower average litter size at birth (P>0.05), they had a similar average litter size at weaning as that of sows fed T1 diet. But,still the sows fed T4 diet had a trend for fewer (P>0.05) total pigs alive at weaning. This is in agreement with the report by Azain (1993), who had stated that there was no difference in number of live pigs at birth or at weaning between those sows fed long chain triglyceride (10% soybean oil) added diet or the control diet from late gestation (day 91 of gestation) to 21 day lactation.

Wilson and Pettigrew (1984) reported average litter size of 9.64 and 10.22 at birth for sows fed control diet and for those fed extra energy (8 MJ DE/d) as tallow for 10 days prepartum. Their average litter size (9.64) for control group is comparable with that of the T1 group and that for their test group (10.22) is comparable to that of group T3 (10) of the present study. Shurson and Irvin (1992) had reported the average litter size at birth as 9.7 for Landrace sows fed supplemental fat (10% corn oil), which is comparable with that of T2 group (9.5).

Lapshin and Matyaev (1994) obtained a litter size of 8.3, 8.9, 10.3, 10.1 and 9.1 at farrowing, respectively for the sows fed 64.6, 94.8, 124.9, 155.1 or 184.8 g of animal fat per day from the start of pregnancy to 109 days of pregnancy. The average litter sizes of the sows fed 300 g (9 piglets) and 200 g (10 piglets) of rendered animal fat in this study are comparable with that of their sows fed either 94.8 g (8.9 piglets) or 184.8 g (9.1 piglets) and those fed either 155.1 g (10.1 piglets) or 124.9 g (10.3 piglets) of animal fat per day, respectively. However, since dietary treatments were imposed on day 100 of gestation, it is unlikely that diet composition contributed to the difference between diets for the total number of pigs born alive. The non significant difference, therefore, seems to have resulted from the random assignment of sows to dietary treatments. The sows selected for this study were multiparous and their parities ranged from 2 to 4. There is also a chance for the parity of sows to affect the total number of pigs born and pigs born alive per litter (Xue *et al.*, 1993 and Cooper *et al.*, 2001). Dyck and Cole (1986) recorded the average litter size at birth for over 2 to 4 parities as 9.6 at birth which is consistent with data for T1 and T2 groups and inconsistent with that of T3 and T4 groups of the present study. Young *et al.* (1990) reported the average litter size at birth of sows fed a gestation energy level of 29.2 MJ DE/d as 8.98, over one to 4 parities which is corresponding to the data of T4 group.

Dyck and Cole (1986) reported average litter size of 8.37 at weaning (28 day lactation) over 2 to 4 parity and this is higher than the observed data for average litter size at weaning (56 days lactation) in this study. This lower average litter sizes can be due to the increased lactation length or increased age at weaning resulting in more piglet mortality due to crushing as in this study and this is in agreement with English *et al.* (1979) who had reported that by reducing the age at weaning by one week, an extra of 0.1 piglet of a litter could be obtainable per sow.

Young *et al.* (1990) reported the average litter sizes of 6.08 and 7.25 at weaning (21 day lactation), respectively, for the sows fed gestation energy levels of 22.2 (low) and 36.2 (high) MJ DE/day over one to 4 parities which are slightly lower than the data obtained in the present study. However, the sows fed with 29.2 MJ DE/day had a litter size of 8.15 which is slightly higher than the values recorded in the present study.

Shurson and Irvin (1992) reported the average litter size of 7.74 at weaning (28 day lactation) for the Landrace sows fed 10 per cent supplemental fat (corn oil) which agrees well with that of the sows fed T3 diet containing 10 per cent added rendered animal fat in the present study (7.75 piglets at 56 days of weaning).

Azain (1993) reported average litter sizes of 9.06, 8.89 and 10.12 at 21 day lactation for sows fed control, long chain triglyceride and medium chanin triglyceride containing diets, respectively and are higher than the observed data in the present study.

5.1.4 Weight of piglet at birth

There is no significant difference in the average birth weight of piglet (P>0.05) between treatments. The sows of T4 group had a trend for heavier piglets than those of T1, T2 and T3 groups and this can be attributed to the increased energy intake of sows during gestation. Though the sows belonging to T2 and T3 groups were fed rendered animal fat at 100 days of gestation, they failed to produce comparatively heavier pigs than those of T1 group. Thus, it is concluded that feeding of rendered animal fat at late gestation has no significant influence on the birth weight of piglets, which is supported by Coffey *et al.* (1982), Azain (1993) and Farmer *et al.* (1996). Hence this non significant difference in average birth weight of piglet between treatments can be attributed to maternal live weight (Whittemore and Morgan, 1990) or to the parity of sows (Cooper *et al.*, 2001) which were randomly assigned to the dietary treatments.

King (1986) obtained an average piglet birth weight of 1.18 kg from the sows fed 5 kg of a standard gestation diet per day which is lower than the corresponding data recorded in the present study.

Young *et al.* (1990) reported average piglet birth weights as 1.31, 1.35 and 1.44 kg, respectively, for sows fed diets containing 22.2, 29.2 and 36.2 MJ DE/day during gestation, which are comparable with that of T3, T2 and T1 groups, respectively, but lower than that of T4 group of the present study. They had also reported the average piglet birth weight as 1.6, 1.6 and 1.5 kg, respectively for sows of parity 2, 3 and 4, of which the average piglet birth weight of sows in parity 4 is nearly equal to that of T1 and T4 groups of the present study.

Babinszky *et al.* (1992) reported the average piglet birth weights as 1.24 and 1.25 kg for sows fed gestation diets containing 5 per cent animal fat and either 13 or 48 mg α-tocopherol and are found to be lower than that of T1, T2, T3 and T4 groups of present study. Yet they were able to obtain an average piglet birth weight of 1.49 kg from the sows fed gestation diet containing 5 per cent animal fat and 136 mg α-tocopherol, which is higher than that of T1, T2 and T3 groups and still lower than that of T4 group of this study.

Shurson and Irvin (1992) recorded average piglet birth weight as 1.5 and 1.51 kg, respectively, for Duroc and Landrace sows fed a gestation diet containing 10 per cent corn oil, comparable to that of T1 and T4 groups, respectively, of this study.

The average birth weight of piglet recorded by Azain (1993) were 1.15, 1.21 and 1.23 kg, respectively for the sows fed a control diet and test diets containing either long chain or medium chain triglycerides are lower than that of the data recorded in the present study.

Lapshin and Matyaev (1994) could obtain an average piglet birth weight of 1.36 kg when the sows were fed 155.1 g animal fat per day from the start of pregnancy to 109 days of gestation. This is comparable to that of T3 group but lower than that of T1, T2 and T4 groups of present study.

5.2 Litter performance

5.2.1 Piglet weight at weaning

There were no significant differences (P>0.05) in the average weaning weights of piglets between the four dietary treatments (Table 9). However, the sows fed T2, T3 and T4 diets had a trend for (P>0.05) higher average weaning weights (8.59, 8.90 and 8.95, respectively) than those fed T1 diet. This trend in increase in the average weaning weights of piglets of sows can be attributed to two major factors namely quantity of sow milk yield (Boyd *et al.*, 1982; Coffey *et al.*, 1982; Lellis and Speer, 1983; Dove and Haydon, 1994 and Farmer *et al.*, 1996) and quality of the sow milk produced (Boyd *et al.*, 1982; Lellis and

Speer, 1983; Hartmann *et al.*, 1984; Shurson *et al.*, 1986; van den Brand *et al.*, 2000 and Mills *et al.*, 2000) and to the factors of minor importance such as breed, age and body weight of sows (Close and Cole, 1986) and the mammary gland size (Nielsen *et al.*, 2001).

The average weaning weights of piglets were recorded as 6.35 kg at 21 day lactation (Boyd *et al.*, 1982), 6.4 kg at 28 day lactation (Reese *et al.*, 1982), 5.2, 4.96 and 5.42 kg at 21 day lactation, respectively, for sows fed 22.92, 29.2 and 36.2 MJ DE/day (Young *et al.*, 1990), 6.94, 6.5 and 7.23 kg at 28 day lactation, respectively, for sows fed diets containing 5 per cent animal fat with three different levels of vitamin E (Babinszky *et al.*, 1992), 7.85 and 8.23 kg, respectively, for Landrace sows fed control diet and test diet containing 10 per cent corn oil (Shurson and Irvin, 1992) and 5.46 or 5.82 kg, respectively, for the sows fed diets containing long chain or medium chain triglycerides (Azain, 1993). The above values were comparatively lower than the corresponding values recorded in the present study. The higher value for average piglets weaning weights recorded in this study may be attributed to the difference in the age at which the piglets were weaned (56 days of age).

5.2.2 Average daily gain of piglets

The average daily gain of piglets of sows given four dietary treatments T1, T2, T3 and T4 were not significantly different ($P>0.05$). This is in agreement with Stahly *et al.* (1980) and Genest and D'Allaire (1995), while Lellis and Speer (1983) reported higher average daily gain upto 21 day lactation. Eventhough there was a numerical increase in the average daily gain of the piglets of T2, T3 and T4 groups compared to that of T1 group, it was not significant between the four dietary treatments.

A perusal of the data presented in Table 9 reveals that the piglets of T2 and T3 groups had a trend for lower average birth weights and higher average weaning weights with a numerical increase in the average daily gain. This is not in agreement with Thompson and Fraser (1988) who had stated that the litters with low birth weight continued to have low gains later in life. Hence, this can be attributed to the presumed increase in the availability of total quantity of milk and milk constituents to the piglets as a result of increased energy intake of the sows (Boyd *et al.*, 1982 and Mills *et al.*, 2000).

King (1986) had reported the average piglet growth rate (g/day) from zero to 28 days of age as 192.8 for the Large White x Landrace crossbred gilts fed lactation diet containing 12.55 MJ DE/kg and 146 g crude protein/kg which is higher than the values recorded in the present study..

Kim and Easter (2001) had reported average daily gain of piglet (from 0 to 21 days of age) as 135, 171, 160, 151, 153, 169 and 136 g, respectively, for the sows nursing 6, 7, 8, 9, 10, 11 and 12 piglets, which are higher than the values recorded in the present study.

5.2.3 Mortality rate of piglets

The average per cent piglet mortality of T1, T2, T3 and T4 groups were 21.10, 20.71, 21.24 and 16.72, respectively (Table 8). There is no significant difference ($P>0.05$) in the per cent piglet mortality between the treatments and is supported by Boyd *et al.* (1978 and 1982) and Pollmann *et al.* (1980). Holness and Mandisodza (1985) observed significantly higher survivability rate with heavier piglets, but not with smaller piglets.

Fahmy and Bernard (1971) reported piglet mortality as 15 to 20 per cent which is comprable with that of the values recorded in the present study. There was a trend for lower mortality rate (16.72%) for T4 group compared to that of T1, T2 and T3 groups. This may be attributed to the variable litter size, since the larger the liter size the higher the competition in litters leading to starvation of weak piglets (Fahmy and Bernard, 1971). The piglet mortality rates reported by English *et al.* (1979), 17.7 per cent for uniform litters is comparable with that of T4 group and 27.7 per cent for variable litters is higher than that of T1, T2, T3 and T4 groups of the present study.

In this study, the great majority of piglet losses took place in the first few days of life and is supported by English *et al.* (1979). The major cause for the piglet mortality in this study was found to be crushing as reported by Edwards (1972) and Genest and De' Allaire (1995). This can also be attributed to the variation in litter weight that affected the possibility of the piglet to regularly consume adequate amount of milk during the first days of life leading to hypothermia and weakness, making the piglets being easily crushed by the sow (Fahmy and Bernard, 1971). English *et al.* (1979) estimated that the crushing accounted for 18 per cent of piglet mortality.

5.3 Digestibility coefficients of nutrients

The data on the digestibility coefficients of the nutrients of the four experimental diets T1, T2, T3 and T4 are given in Table 12.

5.3.1 Digestibility coefficients of dry matter

The average values of digestibility coefficients of dry matter of the four experimental diets T1, T2, T3 and T4 were 69.11, 70.65, 72.04 and 72.92 respectively. The dry matter digestibility was found to improve linearly with increase in energy content in the feed. There were no significant differences observed between the four dietary treatments in the digestibility of dry matter ($P>0.05$). This is in agreement with Boenker *et al.* (1969) who had reported that the added animal fat did not affect the digestibility of dry matter and Kemp *et al.* (1987) who reported that either high or low feeding level had no significant effect on the digestibility of dry matter. Dhudapker *et al.* (1971) obtained dry matter digestibilities of 72.2 and 70.9 per cent respectively, when Middle White Yorkshire growing pigs were fed diets containing 3000 and 3200 kcal of digestible energy per kg and 18.0 per cent crude protein. These values are comparable with the dry matter digestibilities recorded in the present study. Liao and Veum (1994) on the other hand had contradicted the observation in the present study and recorded significantly higher dry matter digestibility coefficients values, viz. 86.6 and 88.1 per cent for pregnant gilts fed diets containing 5.1 per cent and 22.24 per cent animal fat, respectively.

5.3.2 Digestibility coefficients of crude protein

The average values of digestibility coefficients of crude protein of the four experimental diets T1, T2, T3 and T4 were 86.27, 87.73, 87.49 and 88.10, respectively and there were no significant differences between the dietary treatments ($P>0.05$). This is in agreement with Boenker *et al.* (1969) and Kemp *et al.* (1987). Dhudapker *et al.* (1971) reported average digestibility coefficients of crude protein as 73.3 and 77.1 per cent respectively for growers fed with rations containing 3000 and 3200 kcal of digestible energy per kg and 18.0 per cent crude protein. Kemp *et al.* (1987) reported digestibility coefficient of crude protein as 74.0 per cent for sows fed at high level (1.35 x maintenance) as well as low feeding levels (1.1 x maintenance). The values recorded by them are lower than those obtained in the present investigation.

5.3.3 Digestibility coefficients of ether extract

The average values of digestibility coefficients of ether extract of T1, T2, T3 and T4 experimental diets were 84.13, 89.49, 90.13 and 90.30, respectively. It was observed that as the level of rendered animal fat increased, the digestibility coefficients of ether extract was also increased significantly ($P<0.01$) and is in agreement with Just (1982), Grandhi (1994), Lapshin and Maytaev (1994), Liao and Veum (1994) and Overland *et al.* (1994). Liao and Veum (1994) recorded fat digestibilities of 67.6 and 90.1 (similar to that of T3 and T4 groups) for pregnant gilts fed diet containing 5.1 per cent lard and 22.24 per cent lard, respectively.

This increased digestibility of ether extract is probably the result of added animal fat having a higher digestibility than the fat in the feed ingredients, and also due to the fact that endogenous faecal fat excretion becomes a smaller percentage of apparent faecal fat excretion with increasing concentration of added dietary fat (Just, 1982).

5.3.4 Digestibility coefficients of crude fibre

The average digestibility coefficients of crude fibre were 32.56, 28.79, 26.24 and 25.1, respectively for T1, T2, T3 and T4 groups. This gradual decrease in the digestibility of crude fibre with the increasing levels of animal fat in the experimental diets was highly significant ($P<0.001$) and is not in agreement with Low (1985). The digestibility coefficients of crude fibre reported by Rekha (2001) such as 32.2, 27.4 and 21.6 respectively, for crossbred grower pigs fed rations containing 2800, 3000 and 3200 kcal digestibility energy per kg (DE/kg) and that reported by Reddy *et al.* (1986) such as 33.00 and 29.07, respectively for indigenous pigs given diets with 16 per cent crude protein and 3.0 and 2.7 Mcal of DE/kg of the diet are comparable with the values recorded in the present trial.

Dhudapker *et al.* (1971) obtained crude fibre digestibilities of 36.2, 33.7 and 47.0 respectively when pigs were given diets containing 3500, 3200 and 3000 kcal of DE/kg. Ranjhan *et al.* (1972) obtained values ranging from 30.7 to 46.2 for diets varying with crude fibre levels. The values obtained by the above authors are higher than those observed in the present study.

5.3.5 Digestibility coefficients of nitrogen free extract

The average digestibility coefficients of nitrogen free extract were 79.52, 80.29, 82.63 and 83.31, respectively for T1, T2, T3 and T4 groups. This gradual increase in the digestibility of nitrogen free extract with increasing fat level was significant ($P<0.05$) and is in agreement with that reported by Lapshin and Matyaev (1985).

5.4 Economics of gain

The cost benefit ratio of inclusion of rendered animal fat at different levels in late gestation and lactation diets of sows, in terms of the performance of sows and piglets was calculated taking into account only the cost (Rs.) of average piglet weight produced per sow (@ Rs.100 per kg live weight at weaning), economic loss (Rs.) due to the lactation body weight loss of sow (@ Rs.30 per kg live weight) and the total cost (Rs.) of the experimental diet fed (Table 14). Thus, the cost benefit ratios were 1:2.36, 1:2.51, 1:2.54 and 1:2.56, respectively for T1, T2, T3 and T4 groups. The ratios were numerically higher for the fat supplemented groups compared to that of the control group. There is also an increasing trend in the benefit gained from T2, T3 and T4 groups as the level of rendered animal fat addition is increased. Hence considering the reduced lactational stress to the sows (in terms of reduced lactational body weight loss), the predicted better body condition and better rebreeding performance of sows in their future reproductive life, it is concluded that the rendered animal fat can be included in the sow's diet at late gestation and lactation at 15 per cent level of the daily standard ration (containing 3300 kcal DE/kg and 18 per cent crude protein) for better economics of gain and is supported by Joseph Mathew (1992). But, Cheeke (1999) had reported that feeding of high-fat diets is not always economical.

It is, therefore, suggested that for the added rendered animal fat to be more cost effective, it is essential to analyse the prevailing conditions and the current prices of other conventional feed ingredients and animal fats from different sources.

An overall critical evaluation of the results obtained in the present study indicates that Large White Yorkshire sows can be fed rendered animal fat in late gestation and lactation at 15 per cent level of the ration containing 3300 kcal digestible energy per kg and 18 per cent crude protein.

Summary

6. SUMMARY

A study was conducted to assess the influence of inclusion of rendered animal fat (a slaughter house by-product) in the diet of sows at different levels in late gestation and lactation on their litter performance till weaning (56-d lactation). Thirty-two Large White Yorkshire sows at late gestation (100 days of gestation) belonging to the Centre for Pig Production and Research, Mannuthy, were selected and were divided into four equal groups, T1, T2, T3 and T4 of eight replicates each. The eight gestating sows forming the replicates of each group were housed individually. Each group was randomly allotted to one of the four dietary treatments viz., T1 (standard ration – containing 18% crude protein and 3300 kcal DE per kg), T2 (standard ration + 5 per cent rendered animal fat), T3 (standard ration + 10 per cent rendered animal fat) and T4 (standard ration + 15 per cent rendered animal fat) from late gestation (100 days of gestation) to weaning (56 days of lactation).

The total duration of the study was from late gestation (100 days of gestation) to weaning (56 days lactation). The sows were fed twice daily @ 2 kg and 2.5 kg per day at gestation and lactation, respectively. During lactation, the nursing sow was fed extra feed @ 200 g per piglet per day. After weaning of piglets, a digestibility trial was conducted in sows to determine the digestibility coefficients of nutrients. The records of daily feed intake of sows were maintained throughout the experiment. The litter size and weights of

piglets at birth and at weaning, body weights of sows at postpartum and post-weaning periods were recorded during the experiment.

There were no significant differences (P>0.05) between the four dietary treatments for the average lactation body weight loss of sows; for the average litter size at birth and at weaning; for the average piglet weight at birth and at weaning and for the average per cent mortality of piglets.

The sows belonging to T3 group had a trend for higher litter size at birth (10.0, 9.6, 9.5 and 9.0 of T3, T1, T2 and T4 group sows, respectively) and at weaning (7.75, 7.5, 7.5 and 7.38 of T3, T1, T2 and T4 group sows, respectively). The sows fed T4 diet had a trend for higher piglet weight at birth (1.54 kg) compared to those fed T1, T2 and T3 diets (1.47, 1.40 and 1.38 kg, respectively). There was a trend for higher piglet weight at weaning as the level of rendered animal fat in the diet was increased (7.96, 8.59, 8.90 and 8.95 kg, respectively of sows fed T1, T2, T3 and T4 diets). The sows belonging to T4 group had a trend for lowered average per cent mortality of piglets (21.1, 20.71, 21.24 and 16.72%, respectively for T1, T2, T3 and T4 groups).

It was observed that increasing energy density of the diet due to the addition of rendered animal fat significantly decreased (P<0.001) the digestibility of crude fibre for those sows fed T2, T3 and T4 diets than those fed T1 diet. Increasing levels of rendered animal fat in the standard ration was also found to increase the digestibility of ether extract (P<0.01) and the nitrogen free extract (P<0.05). There were no significant differences between the four dietary treatments ($P>0.05$) in the digestibility of dry matter and crude protein for the sows.

The cost benefit ratios of the four dietary treatments T1, T2, T3 and T4 were 1:2.36, 1:2.51, 1:2.54 and 1:2.56, respectively, which revealed an increasing trend in the economics of gain from the sows fed T2, T3 and T4 diets than those fed T1 diet, and this increasing trend in the economics of gain was positively related to the increasing levels of rendered animal fat in the diets.

From an overall assessment of the results obtained during the course of the present investigation, it is reasonably concluded that the Large White Yorkshire sows at late gestation and during lactation can be fed rendered animal fat @ 15 per cent of standard ration containing 3300 kcal DE per kg and 18 per cent crude protein without any deleterious effect, for an improved productive performance of sows and improved growth performance of piglets upto 56 days of age and for a better economics of gain.

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INFLUENCE OF RENDERED FAT IN THE DIET OF LARGE WHITE YORKSHIRE SOWS ON LITTER PERFORMANCE

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ABSTRACT OF THE THESIS

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ABSTRACT

A study was conducted to assess the influence of rendered fat in the diet of Large White Yorkshire sows on their litter performance. Thirty-two Large White Yorkshire gestating sows at late gestation (100 days of gestation) formed the experimental animals. Four groups with eight replicates each were maintained under four experimental diets, viz., T1 (standard ration – containing 18% crude protein and 3300 kcal DE/kg), T2 (standard ration + 5 per cent rendered animal fat), T3 (standard ration + 10 per cent rendered animal fat) and T4 (standard ration + 15 per cent rendered animal fat) from late gestation (100 days of gestation) to weaning (56 days of lactation).

There were no significant differences ($P>0.05$) observed between the four dietary treatments for the parameters observed such as litter size and piglet weight at birth and at weaning, average daily gain of piglets, body weight loss of sows during lactation and piglet mortality. But there was a trend for reduction in lactational body weight loss of sows fed T2, T3 and T4 experimental diets.

The digestibility coefficients of nutrients such as ether extract ($P<0.01$) and nitrogen free extract ($P<0.05$) were found to get improved, that of crude fibre was found to be decreased ($P<0.001$) and that of dry matter and crude protein were not affected ($P>0.05$) with the increasing energy density of the experimental diets.

The cost benefit ratios showed an increasing trend in the economics of gain from the sows fed rendered animal fat added gestation and lactation diets than that of the control sows.

The above results indicate that the rendered animal fat, as an energy source for Large White Yorkshire sows, can be added extra at 15 per cent level of the standard ration (containing 3300 kcal DE/kg and 18% crude protein) during late gestation and lactation, to improve the performance of sows and the litter and to have a better economics of gain.